BULLETIN NO. 69.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS.
A. C. TRUE, Director.

EXPERIMENTS

ON THE

METABOLISM OF MATTER AND ENERGY IN THE HUMAN BODY.

BY

W. O. ATWATER, Ph. D., AND F. G. BENEDICT, Ph. D.

WITH THE COOPERATION OF

A. W. SMITH, M. S., AND A. P. BRYANT, M. S.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., July 7, 1899.

SIR: I have the honor to transmit herewith a report of six experiments on the metabolism of matter and energy in the human body by W. O. Atwater, special agent in charge of nutrition investigations, and F. G. Benedict, expert assistant in the investigations, with the cooperation of A. W. Smith and A. P. Bryant.

These experiments form a part of a series which are in progress at Wesleyan University, Middletown, Conn., and were made with the Atwater-Rosa respiration calorimeter described in previous bulletins of this Office (44 and 63). The ultimate object of this series of experiments is a study of the fundamental laws of nutrition. A necessary preliminary to such a study was the development of apparatus and methods for the accurate measurement of the income and outgo of matter and energy. As the experimental data obtained show, the apparatus and method have now reached a degree of perfection which encourages the hope that they will yield results of the highest value when applied to the study of such questions as the functions of the different classes of nutrients, the demands of the body under different conditions, etc.

An incidental feature of two of the experiments reported was a partial study of the food value of alcohol when used in limited quantities in the daily diet. The study of this question was undertaken at the instigation of the Committee of Fifty for the Investigation of the Drink Problem for the purpose of securing more accurate and scientific knowledge of the physiological action of alcohol. Financial aid for this work was furnished by the Committee of Fifty, from the Elizabeth Thompson and Bache funds, and from private sources.

Special mention should be made of the valuable assistance rendered by Messrs. O. S. Blakeslee, H. M. Burr, and O. F. Tower in the prosecution of the work here reported.

The connection of Prof. E. B. Rosa with the development of the respiration calorimeter and the investigations made by its use is indicated by his joint authorship with Prof. W. O. Atwater of the previous bulletin of this series (63), which describes the apparatus in detail and summarizes the results of two of the experiments reported in detail in this bulletin.

The report is respectfully submitted, with the recommendation that it be published as Bulletin No. 69 of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

METABOLISM OF MATTER AND ENERGY IN THE HUMAN BODY.

INTRODUCTION.

The present report describes in detail six of a series of experiments upon the metabolism of matter and energy in the human body. These experiments were made with the respiration calorimeter described in detail in a previous bulletin,[1] which also summarized the results of two of the six experiments here described. Four experiments in which only the balance of income and outgo of matter was determined were previously made with this apparatus, or, more accurately speaking, that portion of it which is properly called a respiration apparatus, and reported in Bulletin 44 of this Office.

The ultimate purpose of the research to which these experiments belong is the study of some of the fundamental laws of nutrition. The plan of the whole inquiry is based upon the principle that the chemical and physical changes which take place within the body, and to which the general term "metabolism" is applied, occur in obedience to the laws of the conservation of matter and energy. That the law of the conservation of matter applies within the living organism no one would question. It might seem equally certain that the metabolism of energy within the body takes place in accordance with the law of the conservation of energy. The quantitative demonstration is, however, desirable, and an attested method for such demonstration is of fundamental importance for the study of the general laws of metabolism of both matter and energy.

Accordingly the more immediate object of the present inquiry has been to develop an apparatus and method of inquiry by which the metabolism of both matter and energy in the body could be quantitatively measured and the action of the law of the conservation of energy demonstrated, if practicable. It was believed that if this first object could be accomplished, at least within reasonable limits, it would be possible to devise and carry out experiments for the satisfactory study of a number of important questions, including among others the functions of the several classes of nutrients of food and the demands of the body under the different conditions.[2]

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[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63. See also Bul. 44 of the same office and account of the apparatus as a calorimeter and of the results of experiments in Storrs (Conn.) Sta. Rpt. 1897, p. 212.

[2] For further statements upon this subject see U. S. Dept. Agr., Office of Experiment Stations Bul. 63, pp. 7–12, and Bul. 21 of the same office, pp. 99–135. For a discussion of the sources of error in these experiments see Bul. 63, just mentioned, pp. 90–94.

We need to know more than we do at present of the ways in which the different materials are used in the body for the building or repair of tissue or the yielding of energy. It is desirable to learn whether in their service as fuel to supply the body with muscular power and heat their physiological value is or is not equal to their calorimetric value. To put it in another way, we need to learn not only whether the total energy of different food materials is transferred into kinetic energy in the body, but also under what circumstances and to what extent the body avails itself of that energy. To this end it is desirable to experiment with as large a variety of materials as possible, including common forms of proteids, fats, sugars, and starches.

The experiments here reported give data bearing upon the metabolism of matter and energy, the conservation of energy, and the action of the ordinary nutrients of food in the body. They thus bear upon all of the subjects just indicated.

In addition to this some studies of the nutritive action of alcohol were made at the instigation of the Committee of Fifty for the Investigation of the Drink Problem. The committee wished more accurate and scientific information concerning the physiological action of alcohol than has been hitherto possible to obtain. To this end a considerable sum has been devoted by the committee from its own treasury for the prosecution of these experiments. This sum has been supplemented by other gifts from private sources and also by appropriations from the Elizabeth Thompson and Bache funds. The same laboratory privileges which have been extended by Wesleyan University to the general nutrition investigations conducted at that institution under the auspices of the U. S. Department of Agriculture and the Storrs Experiment Station have been extended to this special investigation. By a fortunate cooperation of the several agencies named a considerable amount of inquiry has been possible. Although this alcohol investigation has been conducted with funds which were not supplied by the Department, it is entirely fitting that the details of the investigation, so far as it is of special interest in connection with the laws of nutrition, should be published in connection with the other metabolism experiments of this series. They are, accordingly, included in the series herewith reported. Experiments Nos. 7 and 10 are so-called alcohol experiments—that is to say, the daily menu in each of these experiments included a certain amount of alcohol which replaced an isodynamic amount of fats, sugars, and starches. In some of the later experiments, not reported here, it has likewise replaced the equivalent sugar, starch, and fat, and in still others it has been added to the nutrients of an otherwise duplicate experiment.

GENERAL PLAN OF THE APPARATUS AND OF THE EXPERIMENTS.

The name "respiration calorimeter" as applied to the apparatus used in these experiments is suggested by the fact that it is essentially a respiration apparatus, with appliances for calorimetric measure-

ments. As a respiration apparatus it is similar to that of Pettenkofer. As an instrument for measuring heat it is essentially a calorimeter. The heat is absorbed and carried away by a current of water as rapidly as it is generated in the chamber. It is therefore a water calorimeter. The arrangements for the measurement of both the respiratory products and the heat given off by the body differ in important respects from those of any other apparatus with which we are familiar. The essential features of the apparatus are:

(1) A chamber in which the subject of the experiment—a man—lives, eats, drinks, sleeps, and works during a period of several days and nights. The chamber is 2.15 meters (7 feet) long, 1.22 meters (4 feet) wide, and 1.92 meters (6 feet 4 inches) high. It is furnished with a folding chair, table, and bed.

(2) Arrangements for ventilation by means of a current of air which is drawn from out of doors and passes through the chamber. The ventilating current of air is maintained, its volume is measured, and samples are taken for analysis by a specially devised apparatus designated as a meter pump. The temperature of the air current is measured and so regulated as to be the same on entering the chamber as upon leaving it. The samples for analysis are taken before it enters and after it leaves the chamber. The results of the analyses, with the volume as measured, serve as data for computing the amounts of carbon dioxid and water given off from the body through the lungs and skin.

(3) Arrangements for passing the food and drink into the chamber and removing the solid and liquid excreta. Weighings and analyses of these materials, including determinations of nitrogen, carbon, and hydrogen, give data for calculating the income and outgo of nitrogen; and, taken in connection with the determinations of carbon dioxid and water in the respiratory products, show the income and outgo of carbon and hydrogen of the body. The analyses of the food and solid and liquid excreta include also determinations of proximate ingredients, and thus serve for determining the so-called digestibility of the food, i. e., the proportions of nutrients actually made available.

(4) Arrangements for measuring the heat given off from the body of the man in the chamber, and the heat equivalent of the muscular work done. The heat given off is carried away by a current of cold water, which passes through a series of pipes, called absorbers, inside the chamber. By regulating the temperature of the water as it enters, and also its rate of flow through the pipes, it is possible to carry away the heat just as fast as it is generated, and thus maintain a constant temperature inside the chamber. The amount of outgoing water and its increase of temperature are measured, thus determining the amount of heat carried away.

In order that the heat taken up and carried out by the cold water passing through the absorbers shall represent exactly the amount given off from the man's body or otherwise produced in the chamber, it is necessary to provide that there shall be no passage of heat through the

walls of the calorimeter, or rather that the small quantities that pass in and out shall exactly counterbalance each other; and that the ventilating current of air shall leave the chamber at the same temperature as it enters, so that it shall carry out neither more nor less heat than it brings in. The special apparatus and methods for accomplishing these two objects are described in detail in a previous bulletin.[1]

The excess of water vapor in the air leaving the chamber over that in the air entering represents the water given off from the body of the subject, and the heat required to vaporize it must be added to the heat carried off by the current of water to obtain a true measure of the total heat given off by the subject.

The heats of combustion of the food and of the unoxidized compounds of the feces and of the urine are determined by use of a bomb calorimeter.[2] These data with those for heat given off in the chamber, allowance being made for temperature of food and drink passed in and excretory products passed out of the chamber, serve for computing the income and outgo of energy of the body.

CHECK EXPERIMENTS TO TEST THE ACCURACY OF THE APPARATUS AND METHODS.

In order to test the accuracy of the apparatus as a calorimeter and the methods for determining the income and outgo of matter, two series of experiments were made. For the details of the experiments and the explanations of the methods employed reference may be made to the detailed description referred to above.[3] In the first series a known amount of heat was generated within the chamber by means of an electric current. In the second series alcohol was burned within the chamber, thus producing not only a known amount of heat but at the same time a known quantity of carbon dioxid and water.

THE ELECTRICAL TESTS.

The tests were made by passing an electric current through a resistance coil placed within the chamber, the voltage at each end of the coil and the current passing through the coil being measured. These, with the time during which the current was maintained, gave data for the computation of the amount of total heat generated within the chamber. The heat given off was measured in the manner already indicated by determining the increase in temperature of a known amount of water passing through the chamber. The agreement of these two quantities was taken as the test of the accuracy of the apparatus as a calorimeter. Five tests in all have been made. The results are summarized in the following table. The total heat, as measured by the water current,

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 21, and Storrs (Conn.) Sta. Rpts. 1894 and 1897.

[3] U. S. Dept. Agr., Office of Experiment Stations Bul. 63.

differed from the theoretical amount (generated in the chamber) in all cases by less than 0.5 per cent of the latter. In the average of all the tests made the two amounts are practically identical.

TABLE 1.—*Summary of electrical tests.*

Test No.	Date.	Duration.	Heat generated.	Heat measured.	
	1897.	*Hours.*	*Calories.*	*Calories.*	*Per cent.*
1	March 20	$13\frac{1}{3}$	989.1	992.9	100.39
2	March 25	6	522.1	522.1	100
3	March 26	$7\frac{1}{3}$	1,253.1	1,250.9	99.75
4	April 30	6	21.5	21.4	99.54
	Total, 4 tests	$32\frac{2}{3}$	2,785.8	2,787.3	100.06
	1898.				
5	January 8	4	230.5	229.4	99.52
	Total, 5 tests	$36\frac{2}{3}$	3,016.3	3,016.7	100.01

THE ALCOHOL TESTS.

The conditions in the above tests differed from those which obtain in actual experiments with men in that there was no ventilating current of air passing through the chamber and no carbon dioxid or water was given off within it. The crucial test of the accuracy of the apparatus and methods must be made under circumstances closely similar to those of the actual experiments.

In the burning of ethyl alcohol in air, carbon dioxid, water, and heat are produced. If known quantities of alcohol be burned inside the chamber while a current of air is passing through, the conditions approach very closely to those of the experiment with man. To make such experiments reliable as tests of the accuracy of the apparatus and methods, the combustion of the alcohol must be complete and the amount burned must be exactly known.

THE COMPLETE COMBUSTION OF ALCOHOL.

Previous to the selection of alcohol as the material to be burned as a means of generating known amounts of carbon dioxid, water, and heat, several other substances were tried, the object being to find one which could readily be obtained in a high state of purity, and could without difficulty be completely oxidized in the chamber. The use of stearine candles, so often resorted to by previous experimenters, had been shown to be objectionable because of the incomplete oxidation of the gases of combustion formed, if for no other reason.

Several experiments in this direction were made with benzene, ether, and ethyl alcohol, each of which is readily obtained in sufficiently pure form. In order to avoid the use of a wick an attempt was made to convert the substances into a fine spray and thus secure the presence of a large amount of air in the vapor undergoing combustion. It was easy to produce a fine spray but the oxidation was incomplete, as was

shown by the sooty flames and odors. An attempt was made to secure a wick free from carbon by the use of asbestus, but owing to the poor capillarity of the latter a constant rate of combustion could not be maintained. Various modifications of the method by the use of asbestus were tried, but without success. Either the rate of combustion could not be regulated or the oxidation was not complete.

The method of securing the complete combustion of ethyl alcohol, which proved most satisfactory and was afterwards used in the alcohol tests of the accuracy of the measurements of carbon dioxid, water, and heat in the calorimeter, was as follows:

The essential feature of the flame was a central draft of air. To secure this an ordinary small kerosene lamp with an Argand burner and chimney was found very satisfactory; that is to say, the alcohol was used in this simple lamp in exactly the same way that kerosene would be burned. The flame of the burning alcohol was nonluminous, but it still remained to show conclusively that there was no trace of unoxidized material in the vapors from the burning alcohol. If the supply of oxygen is insufficient, several products are, at least theoretically, capable of being formed. Such products are carbon monoxid, aldehyde, acetic acid, and hydrocarbons.

In order to test for these compounds, it is first necessary to free them from the carbon dioxid and water—that is, from the products of complete combustion of the burning alcohol. For this purpose the lamp in which the alcohol was burning was placed under an inverted funnel, the stem of which was sealed to a glass tube connected with a system of tubes and solutions for the removal of different combustion products from the air. A strong suction from a water pump maintained a current of air through the whole system, so that a large proportion, assumed to be nearly all, of the products of combustion were drawn in and through the apparatus along with some of the air from the room. The current thus passing in at the inverted funnel was first drawn through bottles containing a saturated solution of caustic potash, which sufficed for the removal of practically all the carbon dioxid and water, as well as volatile liquids formed from the incomplete combustion of the alcohol. Tests for such substances were subsequently made by another method. For the removal of the last traces of carbon dioxid, soda lime contained in U-tubes, was employed. A clear solution of barium hydroxid inserted in the system showed that the removal of carbon dioxid was complete.

Gaseous hydrocarbons and carbon monoxid that might have been formed by incomplete oxidation of the alcohol are practically insoluble in caustic potash solution, and their presence in the air current freed from carbon dioxid is easily established by passing the air through a short combustion tube containing granulated cupric oxid heated to redness, and finally through a solution of barium hydroxid. In this way any incompletely oxidized gas would be oxidized to carbon dioxid, which would produce a turbidity or precipitate in this latter solution.

A preliminary test was made by drawing ordinary room air through the apparatus in order to demonstrate the absence of any hydrocarbons or carbon monoxid. The barium hydroxid solution remained clear. The alcohol lamp previously described was then placed under the funnel of the apparatus and lighted. The flame of the burning alcohol was nonluminous. Two hundred grams of 90 per cent alcohol was burned at the rate of about 1 gram in two minutes. At the end of this period of nearly seven hours there was no cloudiness in the barium hydroxid solution, indicating that no products of incomplete combustion had passed the potassium hydroxid solution.

While such a test as that just described indicates that no gaseous products of incomplete combustion are formed when alcohol is burned in a lamp supplied with an Argand burner, provided the flame is nonluminous, it is possible that a considerable amount of liquid products might be formed, and even a trace of alcohol might be volatilized unburned.

In order to determine whether such compounds of incomplete oxidation were present, a second test was made, in which the products of combustion resulting from the burning of 500 grams of alcohol were passed through two flasks surrounded by a freezing mixture of salt and ice to condense all volatile nongaseous products. The condensed compounds, amounting to 150 cubic centimeters, were carefully tested for alcohol and for carbonaceous matter of any kind. A very delicate and easily applied test for small quantities of alcohol has been devised by E. W. Davy.[1] A few drops of the liquid supposed to contain alcohol is added to a solution of one part molybdic acid in ten parts of strong sulphuric acid and the whole gently warmed in a porcelain capsule. If alcohol is present, a blue coloration appears immediately or after a few moments, even when the solution contains no more than 0.1 per cent of alcohol.

Before applying this test to the condensed products of the combustion of alcohol the liquid was first subjected to two fractional distillations, thereby concentrating the volatile products, if such existed, to about 15 cubic centimeters. A few drops of this distillate was tested in the manner just indicated, but the entire absence of any blue coloration in the molybdic solution implied the absence of alcohol. The delicacy of the test was verified by means of a very weak alcoholic solution of known strength. Since the test is sufficiently delicate to show the presence of even 0.1 per cent of alcohol in a solution, it is evident that there could not have been as much as 15 milligrams of alcohol in the condensed products of the combustion of 500 grams of alcohol. In other words, if any were present, there must have been less than 3 parts in 100,000.

It remained, however, to show the absence of any organic matter in the condensed liquid. Accordingly air freed from all traces of carbon dioxid was passed over the remaining portion of the distillate and the

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[1] Allen, Commercial Organic Analysis, 2. ed., Vol. I, p. 59.

vapors passed over hot cupric oxid, as in the first test. The air was then drawn through a tube containing barium hydroxid, but no carbon dioxid was found.

Such tests seemed to show conclusively that there could be no products of incomplete combustion in the burning of alcohol according to this method.

As a final check on the accuracy and delicacy of these methods, one drop of 90 per cent alcohol, or about one-twentieth cubic centimeter, was mixed with 400 cubic centimeters of water and the whole placed in a freezing mixture until all but about 30 cubic centimeters had solidified. This liquid was then poured off and tested for alcohol by means of the molybdic-acid solution above described. A very distinct blue coloration was obtained. A part of the remainder of this extremely dilute alcohol solution was then tested for carbon in the same manner as was employed with the condensed vapors from the burning alcohol, namely, by passing a current of the carbon-dioxid-free air over it and through the combustion tube with hot cupric acid, and finally through barium hydroxid solution. There was a marked cloudiness and white precipitate in the tube containing barium hydroxid. This shows that approximately 1 part of alcohol in 8,000 parts of water can be detected, and it is probable that alcohol and other organic compounds could be detected in a still more dilute solution.

That is to say, a solution of one drop, or about 50 milligrams of alcohol in 400 cubic centimeters of water was frozen until only 30 cubic centimeters remained in liquid form. A portion of this unfrozen liquid revealed the presence of alcohol by the molybdic-acid test. The remainder of this liquid was evaporated in a current of carbon-dioxid-free air which was passed over copper oxid in a combustion tube and then through a barium hydroxid solution. The precipitate in the latter solution showed the presence of organic material in the liquid. This test indicated that the method could be used as a test for minute quantities of alcohol in a liquid. The inference is that any other organic compound, such as acetic acid or aldehyde, that might be contained in the liquid evaporated in the current of air would have been oxidized in the combustion tube, and that its carbon would have appeared as barium carbonate in the barium hydroxid solution.

The products of combustion of alcohol in the lamp were cooled by a similar freezing mixture. The resulting liquid was concentrated to a small bulk by fractional distillation. A portion of this distillate was tested by molybdic acid solution, but gave no reaction for alcohol. The remainder was evaporated in a current of carbon-dioxid-free air and passed over heated copper oxid and through barium hydroxid solution, but gave no reaction for carbon. This negative test, taken in connection with the previous one for the presence of gaseous products of incomplete combustion of alcohol, which was also negative, implied the absence of any considerable amount of incompletely oxidized products of combustion when the alcohol was burned in the lamp.

These tests appear to prove that, if the combustion of alcohol in this form of lamp is not complete, the products of incomplete combustion are so extremely small that they would affect the results, when alcohol is burned in the calorimeter for the production of a known amount of carbon dioxid, water, and heat, by less than 0.01 per cent, a value far within the limits of experimental error.

THE RESULTS OF ALCOHOL TEST EXPERIMENTS.

In the detailed description of these experiments in the previous bulletin it was explained that ethyl alcohol of about 90 per cent was used. The theoretical quantities of carbon dioxid and water which would be produced by its combustion were computed from the known composition of ethyl alcohol and water and the amounts of these materials in the alcohol actually used. The heat of combustion was determined by burning specimens of the alcohol with oxygen in the bomb calorimeter above referred to. Different determinations of the heat of combustion made by this apparatus agreed with tolerable closeness. The average of the results was not far from that obtained by Berthelot. We can hardly believe that the heats of combustion as thus determined were very far out of the way.[1]

In the test experiments the alcohol was burned inside the respiration chamber by use of the lamp above described. The general method of conducting the experiments was the same as followed in the metabolism experiments with a man inside the chamber.

These tests were made from time to time during the progress of the metabolism experiments described beyond. Table 2 summarizes the final results of nine experiments thus made.

TABLE 2.—*Summary of nine alcohol test experiments with respiration calorimeter.*

Number.	Date.	Duration.		Alcohol burned.	Carbon dioxid.		
					Required.	Found.	Ratio of amount found to amount required.
	1897.	*Hrs.*	*min.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
1	April 27-29	52	31	955.4	1,657.2	1,657.6	100.0
2	May 10-11	29	56	798.8	1,385.6	1,384.4	99.9
3	May 26-27	33	50	505.4	876.7	887.8	101.3
4	October 27-28	34	33	797.7	1,384.8	1,335.7	[96.5]
5	November 2-3	35	09	788.2	1,365.1	1,376.7	100.8
6	December 2	11	39	245.3	423.1	417.6	98.6
	1898.						
7	January 6	5	50	112.2	193.5	193.5	100.0
8	January 24-27	77	57	1,607.8	2,784.4	2,769.7	99.5
9	May 9	35	55	699.7	1,206.9	1,198.9	99.4
	Total *a*	317	20	....	9,892.5	9,886.2	99.9

a Omitting the carbon dioxid and water in test No. 4 and the water in test No. 3.

[1] For detailed results see U. S. Dept. Agr., Office of Experiment Stations Bul. 63.

TABLE 2.—*Summary of nine alcohol test experiments with respiration calorimeter*—Cont'd.

Number.	Date.	Duration.	Alcohol burned.	Water. Required.	Water. Found.	Water. Ratio of amount found to amount required.
	1897.	*Hrs. min.*	*Grams.*	*Grams.*	*Grams.*	*Per cent*
1	April 27–29	52 31	955.4	1,106.1	1,109.7	100.3
2	May 10–11	29 56	798.8	924.8	925.0	100.0
3	May 26–27	33 50	505.4	585.1	627.9	[107.3]
4	October 27–28	34 33	797.7	925.7	1,007.9	[108.8]
5	November 2–3	35 09	788.2	912.3	920.8	100.9
6	December 2	11 39	245.3	283.7	287.5	101.3
	1898.					
7	January 6	5 50	112.2	129.8	131.3	101.2
8	January 24–27	77 57	1,607.8	1,860.8	1,881.6	101.1
9	May 9	35 55	699.7	809.3	807.9	99.8
	Total [1]	317 20	....	6,026.8	6,063.8	100.6

Number.	Date.	Duration.	Alcohol burned.	Heat. Required.	Heat. Found.	Heat. Ratio of amount found to amount required.
	1897.	*Hrs. min.*	*Grams.*	*Calories.*	*Calories.*	*Per cent.*
1	April 27–29	52 31	955.4	6,129.0	6,077.1	99.15
2	May 10–11	29 56	798.8	5,124.2	5,167.1	100.82
3	May 26–27	33 50	505.4	3,242.1	3,217.3	99.25
4	October 27–28	34 33	797.7	5,120.5	5,141.5	100.41
5	November 2–3	35 09	788.2	5,048.4	5,050.0	100.03
6	December 2	11 39	245.3	1,564.8	1,556.8	99.48
	1898.					
7	January 6	5 50	112.2	715.7	731.1	102.15
8	January 24–27	77 57	1,607.8	10,294.7	10,268.5	99.74
9	May 9	35 55	699.7	4,463.4	4,466.0	100.05
	Total [1]	317 20	....	41,702.8	41,675.4	99.93

[1] Omitting the carbon dioxid and water in test No. 4 and the water in test No. 3.

These experiments include all which were carried on up to the close of those with man tabulated beyond, with the exception of one or two which were so vitiated by accident as not to be completed.

The first of the tests reported was made the latter part of April, 1897, immediately before metabolism experiment No. 5. Immediately preceding experiment No. 6 a second alcohol test was made, and preceding No. 7 the third test was carried on. This ended the experimenting until the fall of 1897, when test No. 4 was made. The determinations of carbon dioxid and water in this latter test were not satisfactory, and a fifth test was made, in which the agreement of the determinations of carbon dioxid, water, and heat actually measured, with the theoretical quantities produced by the combustion of the alcohol, was very satisfactory. Metabolism experiment No. 8 immediately followed this

test. The sixth alcohol test experiment was made in the early part of December, 1897, but as the plans for the following metabolism experiment were delayed, another test of short duration, No. 7, was carried on immediately preceding metabolism experiment No. 9. The agreement of theoretical quantities with those actually found was again very satisfactory. In the latter part of January, 1898, the eighth alcohol test experiment was made, following which came metabolism experiments Nos. 10, 11, and 12, with no intervening alcohol check experiments.

Between metabolism experiments Nos. 10 and 11, however, that portion of the heat-measuring apparatus which has to do with preventing any loss or gain of heat by its passage through the metal walls of the chamber was tested to insure its accuracy. In this test there was no current of water flowing through the absorbers, nor was the ventilating air current maintained. The thermal junction circuit between the copper and zinc walls was kept constant, i. e., at zero deflection, by regulating the temperature of the air immediately surrounding the outer (zinc) wall in the usual way.[1] The temperature of the interior of the chamber under these circumstances remained constant during the whole period, six hours, of the test. This implies that the variations in the temperature of the air of the room outside the calorimeter were without effect upon the temperature of the interior of the chamber. This is equivalent to saying that no more heat passed through the walls in one direction than in the other. In order that this should be the case the mean temperature of the copper and zinc walls must have been the same. The zero deflection corresponds to this equality of temperature. The inference is, therefore, that the thermal circuit was in good order. The alcohol test experiment No. 9, after metabolism experiment No. 12, gave results closely agreeing with the theoretical, thus showing the apparatus to be in good order. Since, therefore, the whole apparatus was in good order before metabolism experiment No. 10 and after metabolism experiment No. 12, and the special test between Nos. 10 and 11 implied that the thermal junctions were in order, it seems fair to assume that the results of experiments Nos. 10, 11, and 12 are reliable so far as the condition of the apparatus was concerned.

These individual test experiments continued from five to seventy-eight hours each. The total time was three hundred and seventeen hours. The rate of the burning of the alcohol ranged from 10 to 27 grams per hour, and the strength of the alcohol from 90.21 to 90.63 per cent absolute. The determinations of water in tests Nos. 3 and 4 were not satisfactory. In test No. 3 this discrepancy is apparently accounted for by the fact that the air in the apparatus was much dryer at the close of the experiment than at the beginning, and it is not impossible that the excess of water found may be due to the evaporation of

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[1] For detailed description of this part of the apparatus, see U. S. Dept. Agr., Office of Experiment Stations Bul. 63, pp. 19–21.

moisture from the surface of the absorbers during the experiment. In the metabolism experiments the man within the chamber can weigh the absorbers, and thus the differences in amounts of water condensed upon their surfaces can be determined, but in the alcohol test experiments this is impossible. The endeavor was made to have the conditions inside the apparatus, especially of temperature and moisture, the same at the beginning and the end of the tests. In view of the difficulty of making these conditions actually the same, and the considerable amount of water that may adhere to the surface of the condensers, it is not strange that discrepancies should at times be found in the determination of water in the alcohol test experiments. In actual experiments with man it has not been uncommon to find variations in the weights of absorbers of 100 grams or more between the beginning and the end of the six-hour experimental periods. The reason for the discrepancy in test No. 4 is not so apparent, nor was there any apparent cause for the small proportion of carbon dioxid found. The determinations of heat were, however, very close to the theoretical values, and the test is included in the table with the others. As mentioned above, however, another test was made before the beginning of the next metabolism experiment, in which the results were very close to the theoretical. Omitting the determination of water in tests Nos. 3 and 4, the maximum difference between the amounts of water actually found and the theoretical was 1.2 per cent, and the average difference only 0.6 per cent. Omitting the determination of carbon dioxid in test No. 4, the maximum variation was 1.3 per cent from the theoretical amount, and the average only 0.1 per cent. In test No. 7 the proportion of heat measured is larger than usual. It will be observed, however, that this test continued only through one period of six hours. Some time is required to get the apparatus into equilibrium, and the heat measurements of the first experimental period are accordingly sometimes incorrect. It is, perhaps, hardly fair to include this test with the others, though the period was so short and the quantities involved so small that it does not materially affect the total averages. If it be excluded from the averages the maximum difference between the theoretical and experimental amounts of heat is 0.8 per cent, and the average variation less than 0.1 per cent. In either case, the average variation is only 0.1 per cent.

SUMMARY.

The accuracy of apparatus and methods for the determination of carbon dioxid, water, and heat, which have been previously described and which were used in the metabolism experiments here reported, was tested with an electrical current by which known amounts of heat were produced in the chamber of the apparatus, and by burning alcohol in the chamber and thus producing known amounts of carbon dioxid, water, and heat.

The amounts of heat produced by the electric current and the amounts actually measured by the calorimeter agreed almost exactly; the differences averaged scarcely one ten-thousandth of the whole.

In the tests by the burning of alcohol the differences between the theoretical quantities and those actually found were likewise very small, and averaged: For carbon dioxid one-thousandth, water six-thousandths, and for heat one-thousandth of the whole. To state the case in another way, the determinations of carbon, hydrogen, and heats of combustion of alcohol by the respiration calorimeter are as accurate as are ordinarily obtained by the usual methods of combustion with the combustion furnace and the bomb calorimeter.

These results seem to indicate that the methods of determining the amounts of carbon dioxid, water, and heat given off within the chamber are reasonably accurate and that the respiration calorimeter may be regarded as an instrument of precision.

EXPERIMENTS WITH MEN.

PLAN OF THE EXPERIMENTS.

The plan of the metabolism experiments may be briefly outlined as follows:

A man is selected who is in good health, has apparently normal digestion, and who does not find the confinement in the chamber uncomfortable. A diet is selected which provides materials as palatable and in as much variety as is consistent with convenient preparation and with accurate sampling and analysis. The quantity and composition of the diet are generally such as to maintain the body nearly in nitrogen and carbon equilibrium under the conditions of the experiment, whether of work or of rest. In order that the subject may become accustomed to this diet and reach approximate nitrogen equilibrium with it before the experiment proper begins, a preliminary digestion experiment of four days or more immediately precedes the metabolism experiment. Any change found desirable is made, and the preliminary experiment is continued until nitrogen equilibrium is supposed to be reached. In most cases no change has been found necessary, and the preliminary experiment has continued four days. During the period of the preliminary feeding the subject is in general engaged in his customary occupation, but he conforms his muscular activity more or less to that of the coming experiment. Thus, if this is to be a "work" experiment, he rides on a bicycle or walks a considerable distance each day. If it is to be a "rest" experiment, he avoids all unnecessary exercise.

For supper on the last day (usually the fourth) of this preliminary digestion experiment, about 0.7 gram of lampblack is taken with the food, in order to facilitate the separation of the feces of the preliminary experiment from those of the metabolism experiment proper (see p. 21). The subject enters the chamber on the evening preceding the beginning of the experiment, which commences at 7 a. m.

It is assumed that when the subject has essentially the same activity from day to day, sleeps regularly at night, and takes his meals regularly, the hour just before breakfast will be the one at which the body will be most nearly in uniform condition from day to day. That is to say, it is believed that at this hour there will be the smallest amount of material in the alimentary canal, and that the quantity of glycogen in the muscles and elsewhere will be most nearly the same. Furthermore, during the period of rest at night the evolution of heat, carbon dioxid, and water within the chamber is very nearly constant, and the amount of moisture adhering to the surface of the walls of the calorimeter and to the absorbers is probably less than at any other time.

All the determinations begin at 7 a. m. on the day after the subject enters the chamber, and from this time to the close of the experiment record is kept of all observations which furnish data for computing the income and outgo of matter and energy. The experimental day thus begins at 7 a. m. In the experiments here reported the day is divided into four periods of six hours each.

INCOME OF MATTER AND ENERGY—FOOD AND DRINK.

The income of oxygen furnished by the air was not measured in these experiments, and only the income in food and drink are considered. The drink consisted of water and of "coffee." This coffee infusion is counted as water, since it was found in two tests that it contained no appreciable amount of nitrogen or organic matter. The food materials included lean beef freed from fat, dried beef, deviled ham, eggs, milk, butter, bread and other cereal products, beans, sugar, fruit, and occasionally alcohol.

PREPARATION AND SAMPLING OF FOOD.

Considerable difficulty is experienced in preparing the food in such a manner and in such variety as to provide both for accuracy of sampling and palatability. Upon the accuracy in sampling depends the accuracy of the whole experiment, for unless the sample represents the exact composition of the food consumed by the subject the measurements of the income and outgo of both matter and energy are vitiated. In the earlier experiments, Nos. 5–8, the food was prepared fresh each day, and the effort was made to take the samples in such a manner as to insure as great accuracy as possible. The beef was finely chopped in a meat cutter, made into balls of equal weight, and fried, one-half of each ball being given to the subject and the other half reserved for analysis. In cutting the bread alternate slices were taken for food and for analysis. In experiments in which canned fruit was served a sample can was taken for analysis, as it was found to be impracticable to sample the fruit and liquor accurately. The eggs were all of as nearly the same size and appearance as could be found, and each time

eggs were eaten one was taken for a sample. All the other food materials were sampled by taking aliquot portions at each serving. At the end of the experiment the separate samples of each material were united in a composite sample, which was analyzed in the usual manner.

Experience showed this method of preparing and sampling the food to be open to several objections. It was not certain that the meat taken for analysis did not lose an appreciable amount of water while the portion to be eaten was being weighed. If there were such loss the portion weighed last would be the drier. Even if the weights of meat taken for eating and for analysis from day to day are the same, it does not necessarily follow that the composite sample for analysis will have exactly the same composition as the meat eaten. Another uncertainty has to do with the slight errors which occur if the sample of bread for analysis contained more or less crust than the bread eaten. Still more uncertain is the similarity of composition of two cans of fruit, even though put up by the same firm. While it is probable that the boiled eggs taken for analysis and those eaten were very nearly alike, weight for weight, exact agreement in composition is neither proven nor probable. Similar uncertainties as to the identity of composition of the portions taken for analysis and those eaten might be suggested for the other food materials.

These and similar considerations suggested by the experience in experiments Nos. 5–8 persuaded us that an improvement in the method of preparation and sampling of the food materials was desirable. To this end a diet was selected which was intended to be (1) as simple as possible, (2) subject to little probability of variation from day to day, (3) easily prepared, and at the same time (4) as palatable and agreeable to the subject as practicable. Quantities of each material sufficient for the whole experiment, with allowance for analysis and for loss, were sealed in glass jars, each containing the amount for one meal, before the beginning of the experiment. The perishable materials were sterilized. The only material not thus treated was milk. This was purchased fresh each day and an aliquot sample taken and preserved with formalin. These daily aliquots were united and the composite sample analyzed. In this way the food for each meal was, with the exception of the milk, put in cans and held ready to be passed into the chamber when wanted. This method, it is believed, avoids a large proportion of the errors involved in the ordinary sampling of the food. Since the different food materials were all prepared and canned at the same time from the same lot of material, the contents of one jar or can could not vary greatly in composition from the contents of another jar of the same material. Several jars of each material were taken for analysis, and it is believed that these samples represent very closely the food eaten by the subject, and that the food from day to day would contain very nearly the same quantity of each element and compound.

TEMPERATURE OF MATERIALS INTRODUCED INTO AND REMOVED FROM THE RESPIRATION CHAMBER.

To insure the greatest accuracy in measurements of income and outgo of energy, the temperature of the food and drink as introduced into the chamber, as well as that of solid and liquid excreta as removed, should be known. The errors involved by introducing or removing such materials at temperatures varying but little from that of the chamber, which is usually about 20° C., are but slight, and would, perhaps, in the course of an experiment nearly counterbalance each other. The following precautions, however, were taken. The temperatures of the coffee, milk, and water were measured by inserting a thermometer in the liquid immediately before its introduction into the respiration chamber. Temperatures were read to tenths of degrees centigrade. Beef canned in glass jars was warmed in an ordinary water bath for one hour before use, and the temperature of the air in the water bath taken immediately before the beef was to be used. The bread, butter, cereal products, etc., were placed in a water oven at a temperature of about 20° C., the exact temperature being noted immediately before use. In later experiments the use of the water bath at the ordinary temperature was discarded, the materials being placed on a shelf against the wall of the room and the temperature of the air observed. The variations above or below 20° multiplied by the specific heat of the substance gives a measure of the heat introduced in hot materials or the heat taken up by cool materials.

The urine and feces were usually allowed to remain in the chamber until they attained the temperature of the latter. In some cases where the urine was removed shortly after it was voided its temperature was taken and the proper correction applied.

ANALYSES OF FOOD.

The methods of analysis were mainly those adopted by the Association of Official Agricultural Chemists, but such modifications and changes have been made as experience has shown to be necessary or desirable.[1]

OUTGO OF MATTER AND ENERGY—EXCRETORY AND RESPIRATORY PRODUCTS AND RADIATED HEAT.

INTESTINAL EXCRETA.

The outgo of matter in the feces includes both undigested material and metabolic products. In the experiments no attempt has been made to distinguish between these, and the feces are taken as representing matter and energy unavailable for use in the body.[2]

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[1] See discussion of this subject and description of methods of sampling and of analysis in U. S. Dept. Agr., Office of Experiment Stations Bul. 44.

[2] For further discussion of this subject see Storrs (Conn.) Sta. Rpts. 1896, p. 153, and 1897, p. 163.

Sampling and analysis.—Various methods for the separation of the feces from a given diet from that of the preceding or succeeding diet have been adopted by different experimenters. The method used in these experiments consists in administering a small amount of lamp-black or powdered charcoal in gelatin capsules with the meal immediately preceding or succeeding the diet under investigation. For example, if it is desired to begin with a given diet at breakfast the lampblack will be taken with the supper on the night previous. It has been found that the feces resulting from a meal of bread and milk possess a distinctively characteristic consistency and facilitate to a marked degree the separation of the feces of a mixed diet. It has therefore been our custom to have a considerable amount of bread and milk in the meal with which the lampblack is taken. While this is not as essential as was formerly supposed, it makes the separation more positive and certain. At the same time considerable other food besides bread can be added to the meal without materially altering the consistency of the feces, provided a fairly large amount of milk be included. Experiments have been tried with the use of subnitrate of bismuth. This reagent is colored black in the feces, owing to the formation of bismuth sulphid. While under certain conditions this method of separation may give very excellent results, it is not considered as reliable by any means as the lampblack method.

For the collection of the feces copper cans 16 centimeters long, 11 centimeters wide, and 6½ centimeters deep, of an elliptical cross section, and provided with close-fitting covers, were used. The cans were weighed before being passed into the respiration chamber and the increase of weight on their removal taken as the weight of the fresh feces. The feces after weighing were placed in shallow dishes and dried in a water oven for three or four days, after which they were analyzed according to the usual method.

Loss of nitrogen in drying.—Various experimenters have found a greater or less loss of nitrogen in drying feces from different animals. In the experiments here reported no attempt was made to determine this loss of nitrogen, since preliminary experiments had indicated that, as the drying is actually conducted in this laboratory, the loss is quite small. A later and somewhat extended series of experiments in this laboratory confirmed the previous results, and indicated that the total amount of nitrogen lost in drying the feces from a four-day experiment for twenty-four hours in air in a drying oven at about 96° C. does not exceed half a gram.

URINE.

With the exception of the comparatively small amount of unavailable nitrogen rejected in the feces practically all the nitrogen of the food is eliminated in the urine in the form of urea, uric acid, creatin and creatinin, and allied nitrogenous compounds. The nitrogen in the urine is taken as a measure of the amount of protein compounds metabolized.

While this is the common usage in metabolism experiments, it is of course incorrect in so far as the urine contains creatinin and allied compounds which were in the food. The error thus introduced, however, is not large. The carbon and hydrogen in organic combination in the urine represent partially oxidized compounds, and the heat of combustion of the dried residue of the urine is a measure of the amount of energy which is carried away from the body in these partially oxidized compounds.

Sampling and analysis.—The urine of six-hour periods, beginning with the experimental day at 7 a. m., was collected in glass jars, tightly sealed, and, after remaining in the chamber for about three hours in order to come to the temperature of the apparatus, was passed out through the food aperture. It was then weighed and its specific gravity taken, after which an aliquot portion, usually one-half, was reserved to make a part of a composite sample for the day, and the remainder was used for the determination of nitrogen and other constituents. The nitrogen was determined in the fresh urine by the Kjeldahl method. Portions of 100 or 200 grams of the composite sample for the whole experiment were evaporated to dryness in a partial vacuum, and determinations of carbon and hydrogen were made in this dried residue.

Loss of urea in drying.—Even when urine is dried in a vacuum at comparatively low temperature there is danger of some decomposition by which nitrogen may be lost, in the form either of ammonia or, more probably, of ammonium carbonate. The process of drying is also tedious. For this reason in the latter experiments an attempt was made to dry the urine at 100° C. and to determine the loss of nitrogen during this drying.

In order to estimate the amount of this loss of nitrogen several samples were dried in a flask over a water bath or calcium chlorid bath giving a temperature of from 100 to 105° C. A current of air was forced through the flask by means of a water blast. This air was freed from carbon dioxid by passing it over soda-lime before it reached the flask. The air as it came from the flask was passed through a known amount of a standard solution of acid in another flask, after which it was dried by passing through sulphuric acid and the carbon dioxid removed by soda-lime. After the urine had been brought nearly to dryness in the first flask, the standard acid in the second flask was titrated and the amount of nitrogen in the ammonia which had been absorbed by the acid was calculated. The increase in weight of the soda-lime tube and the sulphuric-acid tube immediately following it gave the amount of carbon dioxid that had been given off from the urine. In two experiments the proportions of nitrogen and of carbon dioxid given off corresponded quite nearly to the proportions in ammonium carbonate. The natural inference was that it would be within the limits of error to assume that all the nitrogen and carbon lost in drying were in ammonium carbonate. Of course this could not be exactly true, because there is a certain amount of free carbon dioxid in the urine.

In experiments Nos. 5, 6, 7, and 8 the urine was dried in a partial vacuum at room temperature, and from the results of several special experiments in which the amount of ammonia given off was determined it was assumed that the loss of nitrogen in the drying was so small that it might be left out of account. In experiment No. 9 and those following, instead of drying the urine in a partial vacuum, as was done in experiments Nos. 5–8, 200 grams of fresh urine was evaporated in a dish over a water bath. The nitrogen was determined in the fresh urine and in the dried residue. The difference between the calculated weights of nitrogen in the 200 grams of fresh urine and in the dried residue was assumed to be due to nitrogen carried away in combination with carbon in the form of ammonium carbonate, and the corresponding loss of carbon was calculated. The loss of hydrogen was so small that it was left out of account.

Heat of combustion of urine.—The heat of combustion of the solid constituents of urine has been determined by two methods, each of which has given, in general, fairly satisfactory results. The most satisfactory method is that described by Kellner.[1] This consists in saturating a cellulose "absorption block" of known weight and known heat of combustion with a known amount of urine, drying in an oven at about 60° C., and burning in the bomb calorimeter. The total heat of combustion of absorption block and dried residue of urine, less that of the absorption block, gives the heat of combustion of the urine. The other method consists in drying the urine in a partial vacuum at ordinary room temperature, or over a water bath, as described above, and burning the dried residue in the bomb calorimeter. As a matter of fact, the dried residue which was prepared for determination of carbon and hydrogen was used for the determinations of heats of combustion. In the few cases in which this method was followed allowance was made for the heat of combustion of the urea estimated to be lost as ammonium carbonate.

The heats of combustion were determined in the urine of the four days of the actual metabolism experiment in each case, but not in that of the four days of the preliminary digestion experiment. The determinations were made in separate samples of the urine of each day and in composite samples of that of the four days. The heats of combustion were determined, both in the separate day samples and in the composite four-day samples, by the Kellner method. For the determinations in the dried residues, when made, only the composite samples were used. The results are given in the tables, for comparison with those obtained by the Kellner method. In the computations of energy of outgo the results from the individual day samples are used.

The nitrogen lag.[2]—As was stated above, the urine in these experiments is collected from 7 a. m. on the beginning of the experimental day until 7 a. m. the next day in periods of six hours. One purpose of

[1] Landw. Vers. Stat., 47 (1896), p. 297.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 44, pp. 35, 36.

this division into periods is to obtain information, if practicable, regarding the nitrogen lag, i. e., the interval of time during which the excretion of nitrogen lags behind the metabolism in the body. We have found comparatively few data for determining the exact duration of this lag. It is not known, for instance, at what time the nitrogen of the food eaten for breakfast begins to appear in the urine, nor when the nitrogen of the food eaten for supper of any given day is all metabolized and excreted. Still less do we know how long a period intervenes between the metabolism of nitrogen of tissue and its excretion. It is believed by some experimenters that, under ordinary conditions, the actual nitrogen consumed in the food is soon excreted. In previous experiments[1] of this series a lag of six hours is assumed in one case and twelve hours in another. One advantage in making the diet uniform for the four days preceding the metabolism experiments, as has been done in the cases here reported, is that during this time the subject will reach approximate nitrogen equilibrium and that for the purpose of the experiment the "nitrogen day," i. e., the twenty-four hours during which the nitrogen is excreted may be taken as coincident with the experimental day, thus allowing for no lag. This probably gives results as nearly correct as would be obtained by any such arbitrary assumption. The data are, however, given in the tables by which the calculations can be revised to allow for a nitrogen lag of six, twelve, or, in some cases, twenty-four hours' duration. For this purpose the nitrogen in the urine is determined for periods of from six to twenty-four hours after the end of each experiment.

PERSPIRATION PRODUCTS—ELIMINATION OF NITROGEN.

The amount of matter eliminated in the perspiration is not large. During several of the rest experiments it was found that the nitrogen thus eliminated amounted to less than 25 milligrams per day. In work experiments, on the other hand, as much as 0.2 gram of nitrogen was eliminated by the skin in a day.

The nitrogen of perspiration was determined as follows: The subject took an ordinary bath and afterward rinsed his body with distilled water before entering the chamber. His underclothing, which was of medium weight, was carefully rinsed with distilled water after the usual washing. He had a clean suit of underclothes every night to replace the suit worn during the day. The latter suit was washed with distilled water, which was then evaporated nearly to dryness and the nitrogen in the residue was determined by the Kjeldahl method. The nitrogen of the products of perspiration was thus determined in rest experiments Nos. 5 and 7, and in all the work experiments.

RESPIRATION PRODUCTS—CARBON AND HYDROGEN.

In all the experiments the only respiratory products determined were carbon dioxid and water. From these the carbon and hydrogen were

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 44, pp. 49, 52, 61.

calculated. The amounts of intestinal gases, as methane, and of other volatile organic products given off from the body of the subject, were believed to be very small and are here left out of account.[1] We hope, however, to find means later for determining these substances, and also for determining the amount of oxygen used from the air current.

The method of measuring, sampling, and analyzing the air of the ventilating current was described in detail in a previous bulletin.[2] In brief, the volume is now measured by a meter pump of special construction, which serves the threefold purpose of maintaining the current, measuring and recording the volume automatically, and delivering aliquot samples of one-hundredths of the whole amount for analysis. In the experiments here recorded, however, samples drawn by aspirators were used for analysis. The aspirators, also described in the bulletin just referred to, are arranged to take samples of both the incoming and outgoing air. The samples are drawn continuously during the six-hour periods. Each sample represents not far from one one-hundred-and-sixtieth of the total current.

These analyses of both incoming and outgoing air were made in duplicate, save that in the earlier experiments, Nos. 5, 6, and 7, the analyses of the incoming air were not duplicated. The justification for omitting the duplicates is found in the fact that the carbon dioxid varies but little from day to day, and still less from six-hour period to six-hour period, and that the water is frozen out of the incoming air current before the sample is taken, so that the amount remaining in this current as actually analyzed is extremely small and quite constant. On this supposition, the analyses of the air of the four six-hour periods serve in a sense the purpose of duplication. In the later experiments, however, duplicate samples of the incoming as well as the outgoing air were taken by the aspirators and analyzed. In still later experiments not yet described, samples of the outgoing air were taken by aid of the meter pumps and analyzed, so that the analysis of the outgoing air was made in quadruplicate.

The samples of incoming and outgoing air were taken by the aspirators from the current immediately before and immediately after it left the chamber of the calorimeter. The water in both the incoming and outgoing air was mostly removed by coolers before the samples were taken. This cooling was accomplished by passing the air through a "freezer" consisting of copper pipes immersed in cold brine, so that the temperature was reduced to not far from —20° C. The freezers in which the outgoing air current was cooled were specially adapted for weighing. In this way the larger portion of the water of respiration and perspiration was condensed, and its amount directly determined. After passing

[1] See Billings, Mitchell, and Bergey, on the Composition of Expired Air and its Effects upon Animal Life, Washington, Smithsonian Institution, 1895; and Bergey, Methods for the Determination of Organic Matter in Air, Washington, Smithsonian Institution, 1896.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 63.

the freezer the air was sampled, and the carbon dioxid and the remaining water were determined. The determination of water was made by passing the sample through a U-tube containing pumice stone saturated with sulphuric acid. The carbon dioxid was removed by soda lime contained in other U-tubes. The exact arrangement of tubes and details of calculations have been referred to in the previous bulletins above cited.

THE DETERMINATION OF ALCOHOL ELIMINATED THROUGH THE KIDNEYS, LUNGS, AND SKIN.

Since a portion of the alcohol ingested may be excreted through the kidneys, lungs, and skin it is essential, in experiments on the metabolism of matter and energy in which alcohol makes part of the diet, to determine the amount of alcohol which thus escapes oxidation.[1] It becomes necessary, therefore, to examine the urine, outgoing air current, freezer water, and drip water for the presence of alcohol. In the last two we should expect to find so much of the alcohol eliminated from the lungs and skin as was condensed with the water either on the absorbers or in the freezers. The remainder of the alcohol from the lungs and skin would be in the air current.[2] The urine and the drip and freezer waters were subjected to fractional distillation to separate the alcohol, which was finally determined by oxidation with chromic acid by the method described by Bodländer.[3] An aliquot sample of the main air current was drawn through bulbs containing concentrated sulphuric acid where all the alcohol vapor was absorbed.[4] The alcohol thus retained was determined, as before, by oxidation with chromic acid. The amount of alcohol thus estimated to be given off from the body unoxidized was in each case very small. The figures for the amounts thus determined in experiment No. 7 are given in Table 41. Similar determinations in experiment No. 10, as made by the modified method described beyond, are shown in Table 83. The highest amount, somewhat over 4 per cent of the amount ingested, was observed on a single day in experiment No. 7.

We have found, however, that these figures are not correct. The method used for the determination of the alcohol in experiment No. 7 involves at least two errors, both of which make the amount as determined too large. One error occurs in the determination of alcohol by the chromate method. The other is due to the presence of reducing material, other than alcohol, in the air. This latter error also applies to the determinations in experiment No. 10. Both of these sources of

[1] It is here assumed that the feces would contain no considerable amount of the alcohol ingested, though they might contain an appreciable amount of alcohol as a product of fermentation. See Bodländer in Arch. Physiol. [Pflüger], 32, (1883), p. 424.

[2] It is here assumed that no considerable amount of alcohol would be absorbed and retained by the clothing.

[3] Arch. Physiol. [Pflüger], 32, (1883), p. 398.

[4] See Benedict and Norris on "The Determination of Small Quantities of Alcohol," Jour. Amer. Chem. Soc., 20 (1898), p. 299.

error have been made the subject of especial investigation in this laboratory.

An account of the investigations upon the chromate method has already been published.[1] From this it appears that in the method described by Bodländer the end reaction is not sharp and, in our experience, the results obtained are too large. In view of the necessity of as accurate measurements as possible of small quantities of alcohol, a modification of this method was devised and has been described.[1] This consists essentially in collecting the alcohol in concentrated sulphuric acid, oxidizing it with potassium bichromate in excess, reducing the remainder of the chromic acid by a slight excess of a solution of ferrous ammonium sulphate and determining the excess of ferrous iron by titration with potassium permanganate solution. The accuracy of this modified method was tested by a considerable number of experiments in which known and very small amounts of alcohol were added to water, to urine, and to a current of air. The results obtained in all these tests were reasonably accurate. In no instance did the error exceed a small percentage of even the very small amount of alcohol used. The details are given in the article referred to.

The quantities of reducing matter in the air were studied by experiments of several kinds. A current of ordinary air drawn through a solution of potassium bichromate in sulphuric acid showed more or less reduction even after passing through tubes packed with cotton. The use of a moistened air filter, as suggested by Remsen,[2] is in these experiments objectionable, because it is desirable to use the same air current for both moisture and alcohol determinations. In several experiments in which the man had no alcohol the quantity of reducing material in the air was determined by the modified method for the determination of alcohol just mentioned; that is to say, the sample of the outgoing air current was drawn through sulphuric acid and the reducing matter determined—as in the case of the alcohol experiments—by the use of chromic acid, ferrous ammonium sulphate, and potassium permanganate solutions. In every case the reduction was considerable, though there were slight variations in the amounts on different days and in different experiments. The amount of reduction in these experiments without alcohol was such as to correspond to from 0.96 gram to 1.20 grams of alcohol in the air from the chamber during a period of twenty-four hours. The amount of reduction found in the experiments in which alcohol formed a part of the diet ranged from 0.71 gram to 1.05 grams in twenty-four hours. In other words, the amount of reducing material in these particular experiments appears to be very nearly the same without as with alcohol in the diet. The natural inference would be that what was called alcohol in the outgoing current of air consisted of other reducing substances. We should, however, be unwilling to make any such positive assertion without

[1] See Benedict and Norris on "The Determination of Small Quantities of Alcohol," Jour. Amer. Chem. Soc., 20 (1898), p. 293.

[2] Natl. Bd. Health Bul., Washington, 1 (1879–80), p. 233; 2 (1880–81), p. 517.

further experiment. Meanwhile we may add that confirmation of the at least approximate correctness of this method of determining the differences in the quantity of reducing matter in the air current and detecting the addition of small quantities of alcohol to the air in the chamber were found in some incidental observations connected with the experiments. In one case, as stated elsewhere, a small amount of coffee containing alcohol was accidentally spilled upon the copper floor of the chamber. As the amount was known, approximately, a corresponding quantity was given to the subject to make up the regular daily ration. The alcohol thus spilled naturally evaporated and was carried out in the air current. The amount of alcohol found for this day in the outgoing air current exceeded the usual amount by very nearly the amount spilled. In an experiment made since those here described alcohol in the form of whisky was taken with sugar and water. The mixing was generally done outside the chamber, but in one case the materials were passed into the chamber separately and there mixed. In the mixing the whisky was poured into a cup and the sugar and water were added later. Opportunity was thus given for an evaporation of a small amount of the alcohol of the whisky. Larger amounts of alcohol were found in the air current than in the other days when the mixing was done outside.

These observations seem to warrant the following inferences: (1) The modified method, as above described, gives a very nearly accurate measure of the small amounts of alcohol and other reducing material in the air current, in the urine, and in the drip water and freezer water; (2) in the determination of alcohol in the air current an allowance should be made for other reducing materials. It seems to us not improbable that allowances should also be made for the small amounts of reducing material other than alcohol in the urine and the freezer and drip waters. The need of further investigation of the subject is evident, and such investigation is now being made. Meanwhile it seems proper to state the amounts as actually found without making corrections. (3) Under the circumstances of these experiments, in which approximately 72 grams of alcohol was administered daily in six doses, the quantity of alcohol eliminated could not have been more than 1½ grams per day, or about 2 per cent of the whole. If an allowance for reducing material other than alcohol in the air current was based upon the determinations thus far made, there would be practically no alcohol remaining which could have been excreted through the lungs and skin, and the total amount which could have been eliminated daily in the urine and otherwise would be inconsiderable.

The details of the determinations of alcohol and other reducing matters are not reported in this bulletin.

It is theoretically possible that products of the partial oxidation of alcohol, such as aldehyde and acetic acid, may have been eliminated by the kidneys, lungs, or skin in these experiments, but we are not aware

of any evidence which would lead us to expect such elimination to any considerable extent. Efforts were made to find evidence of aldehyde and acetic acid in the urine, drip and freezer waters, and outgoing air currents, but not even traces were detected. The tests, however, were not sufficiently delicate to warrant the affirmation that no traces of these substances were present and the time at our disposal did not suffice for devising tests which would be conclusive.

MEASUREMENT OF HEAT RADIATED FROM THE BODY.

The details of the method of measuring the heat given off by the subject were described in the bulletin referred to above. These measurements were made from the time the subject entered the chamber on the evening preceding the commencement until the close of the experiment, at 7 a. m. on the fourth day following. The measurements for the experiment proper began at 7 a m.

DESCRIPTION OF EXPERIMENTS WITH MEN.

In planning a metabolism experiment for the study of a given question, as stated above,. the diet should be arranged to fulfill three conditions: (1) It should be palatable and of such variety that the subject will not tire of it during the experiment: (2) it should furnish the amounts of nitrogen (protein) and energy desired for the purpose of the experiment; and (3) the food materials should be in such forms as to admit of accurate sampling.

In the description of each experiment the menu or ration for each day is shown. A daily programme is made out which serves as a guide both for the subject and for those conducting the experiment. It shows the hours at which the subject is expected to rise and retire, the hours at which he shall receive his meals, and when he shall weigh himself and the system of absorbers inside the apparatus. This programme follows the menu in the description of each experiment.

During each experiment the subject keeps a diary, or record, showing the results of all determinations of weights and temperatures made by himself in the chamber of the calorimeter. A summary of this diary follows the programme in the description of each experiment.

The subject of experiments Nos. 5 to 10 here described was Mr. E. Osterberg, who was also the subject of experiments Nos. 1 and 2, and of a number of later experiments. He was 31 years of age, 5 feet 8 inches (1.87 meters) in height, and weighed about 150 pounds (68 kilograms). He was in excellent health and accustomed, as laboratory janitor and chemical assistant, to moderate muscular labor.

COMPOSITION OF FOOD MATERIALS, ETC., OF EXPERIMENTS NOS. 5-10.

The composition of all the food materials used in the experiments described in this bulletin is given in Table 3, page 30. The methods of analysis were referred to on page 20. Attention is called to the fact

that the protein is in all cases computed by multiplying the total nitrogen by the factor 6.25. In cases where the amount of carbohydrates is so small as to be neglected, as in meats, the sum of the percentages of water, protein, fat, and ash may be more than 100.[1]

TABLE 3.—*Composition of food materials and feces in metabolism experiments Nos. 5–10.*

Laboratory No.	Food material and feces.	Experiment No.	Nitrogen.	Carbon.	Hydrogen.	Water.	Protein (N× 6.25).	Fat.	Carbohydrates.	Ash.	Heats of combustion per gram, determined.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
2783	Beef, dried	5	3.93	17.57	2.25	60.1	24.6	7.8	......	7.6	2.028
2796	.....do	7	3.91	14.31	2.16	65.4	24.4	2.8	......	7.2	1.595
2782	Beef, cooked	5	4.59	19.00	2.69	64.2	28.7	5.5	......	1.8	2.108
2789	.....do	6	4.77	21.28	3.05	60.3	29.8	8.7	......	2.1	2.421
2795	.....do	7	4.08	17.29	2.59	66.8	25.5	6.7	......	1.3	2.010
2821	.....do	8	5.06	21.62	3.11	59.8	31.6	7.1	......	1.7	2.410
2835	.....do	9	4.10	16.35	2.25	67.3	25.6	5.4	......	1.6	1.928
2839	.....do	10	4.34	16.31	2.34	67.6	27.2	3.3	......	1.9	1.816
2788	Ham, deviled	6	2.64	36.11	4.91	42.2	16.5	36.9	......	4.0	4.353
2781	Eggs, boiled	5	2.02	14.89	2.28	74.5	12.6	11.0	......	.9	1.778
2790	.....do	6	2.24	14.39	2.19	73.2	14.0	11.3	......	1.0	1.928
2798	.....do	7	1.60	10.96	1.77	79.9	10.0	9.1	......	.7	1.424
2819	.....do	8	1.98	15.27	2.29	74.3	12.4	10.9	......	1.0	1.796
2785	Butter	5	.17	66.84	10.46	8.1	1.1	88.3	......	2.5	8.052
2793	.....do	6	.16	62.82	10.34	9.3	1.0	87.3	......	2.4	7.954
2801	.....do	7	.19	62.75	9.84	9.7	1.2	85.9	......	3.2	7.929
2827	.....do	8	.25	63.65	10.10	10.0	1.6	85.2	......	3.2	7.777
2833	.....do	9	.19	62.68	10.27	10.2	1.2	84.8	......	3.8	7.761
2843	.....do	10	.10	64.42	10.01	9.9	.6	87.3	......	2.2	7.989
2784	Milk, whole	5	.58	7.58	1.14	85.3	3.6	5.4	4.9	.8	.891
2799	.....do	6	.48	8.27	1.23	85.3	3.0	5.4	5.6	.7	.935
2800	.....do	7	.56	6.76	.99	87.0	3.5	4.8	3.9	.8	.742
2826	.....do	8	.55	7.89	1.15	85.0	3.4	5.1	5.8	.7	.902
2836	Milk, skimmed	9	.52	4.04	.57	90.7	3.3	.1	5.1	.8	.393
2846	.....do	10	.53	4.15	.61	90.4	3.3	.1	5.4	.8	.414
2802	Bread, rye	5	1.37	25.32	3.57	44.0	8.5	.3	45.6	1.6	2. 18
2804	.....do	7	1.34	25.71	3.53	42.2	8.4	.6	47.0	1.6	2.483
2815	.....do	8	1.58	27.65	4.00	37.1	9.9	.1	51.2	1.7	2.748
2803	Bread, white	6	1.33	25.46	3.85	43.9	8.3	1.6	45.0	1.2	2.540
2834	.....do	9	1.34	24.53	3.54	44.7	8.4	.2	44.3	2.4	2.400
2844	.....do	10	1.33	26.15	3.84	41.0	8.3	.2	49.0	1.5	2.553
2830	Wheat breakfast food	9	1.58	41.32	5.78	7.5	9.9	1.6	77.7	3.3	4 071
2840	.....do	10	1.75	41.20	6.03	7.2	10.9	1.5	78.3	2.1	4.052
2831	Maize breakfast food	9	1.78	44.34	6.45	5.6	11.1	8.7	71.1	3.5	4.444
2842	.....do	10	1.88	44.39	6.49	4.9	11.8	8.2	73.4	1.7	4.437
2829	Ginger snaps	9	.96	44.45	6.48	5.2	6.0	9.5	75.6	3.7	4.358
2841	.....do	10	.92	42.73	6.45	4.3	5.8	6.2	80.8	2.9	4.247
2780	Beans, baked	5	1.26	13.53	1.86	68.8	7.9	.6	20.6	2.1	1.341
2791	.....do	6	1.15	12.44	1.73	71.4	7.2	.4	19.2	1.8	1.222
2797	.....do	7	1.00	12.56	1.78	70.9	6.2	1.0	19.9	2.0	1.257
2817	.....do	8	1.05	11.92	1.70	71.9	6.6	.3	19.0	2.2	1.208
2823	Apples	8	.04	6.40	.67	84.8	.2	.5	14.2	.3	.617
2779	Pears, canned	5	.04	7.65	1.18	79.6	.3	.9	19.0	.2	.778

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 44, p. 25.

TABLE 3.—*Composition of food materials and feces in metabolism experiments Nos. 5–10*—Continued.

Laboratory No.	Food material and feces.	Experiment No.	Nitrogen.	Carbon.	Hydrogen.	Water.	Protein (N × 6.25)	Fat.	Carbohydrates.	Ash.	Heats of combustion per gram, determined.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
2792	Pears, canned	6	0.05	7.01	1.18	81.4	0.3	0.2	17.9	0.2	0.759
	Pears, average of 2779 and 2792	7	.04	7.33	1.18	80.5	.3	.5	18.5	.2	.769
2786	Sugar	(1)	......	42.10	6.48	......	......	......	100.0	......	3.960
2806	Feces	5	1.31	10.97	1.47	78.2	8.2	4.5	5.1	4.0	1.141
2808	.....do	6	1.29	10.64	1.56	78.6	8.1	4.1	5.6	3.6	1.194
2810	.....do	7	1.81	13.43	1.77	71.0	11.3	4.9	7.6	5.2	1.530
2825	.....do	8	1.77	14.90	2.04	69.7	11.1	5.9	7.7	5.6	1.643
2838	.....do	9	1.19	12.60	1.74	72.9	7.4	3.9	11.4	4.4	1.343
2848	.....do	10	1.57	13.44	1.82	71.0	9.8	4.2	10.2	4.8	1.445

[1] Used in all the experiments.

DETAILS OF METABOLISM EXPERIMENT NO. 5.[1]

A general description of the routine of the experiments and an explanation of the results as tabulated can best be given in connection with the details of one of the experiments. Number 5, the first of the series here described, will suffice for this purpose, although this, like others of the earlier experiments, is less satisfactory than those made after experience had been gained.

This experiment began May 4, 1897, and continued four days. The preliminary period, which is usually four days, was increased in this case to eight days, as unexpected circumstances delayed the starting of the experiment proper. The subject entered the calorimeter at about 9 o'clock on the evening of May 3. During the night the usual measurements of heat were made and the temperatures of the interior of the chamber—i. e., (1) the air inside, (2) the incoming and outgoing air currents, (3) the two metal walls of the chamber, and (4) the air immediately surrounding the chamber, were brought as near together as practicable; the temperature and rate of flow of the water current were regulated so as to carry out the heat as rapidly as it was given off by the subject, and other details of manipulation were arranged so that when the experiment began at 7 a. m., May 4, everything was in satisfactory condition. The bed and bedding, chair, table, etc., were weighed before and after the experiments, but no appreciable changes in weight were observed. The diet was more varied than that of some of the later experiments. The methods of sampling were not satisfactory, which may account in part for the unusually wide discrepancies between

[1] Experiments Nos. 1 to 4 were reported in Bulletin 44 of this Office. In these the metabolism of matter only was studied.

the theoretical values for income and those actually found for outgo of energy. The daily menu in this experiment was as follows:

TABLE 4.—*Daily menu—Metabolism experiment No. 5.*

Menu.	Grams.	Menu.	Grams.
BREAKFAST.		DINNER—continued.	
Boiled eggs	95	Baked beans	125
Butter	15	Canned pears	150
Milk	250	Sugar	10
Rye bread	100	Coffee	300
Sugar	15	SUPPER.	
Coffee	290	Dried beef	25
DINNER.		Butter	10
Beef, fried	120	Milk	500
Butter	10	Rye bread	125
Milk	25	Sugar	10
Rye bread	100	Coffee	300

The beef was cooked in the form of "Hamburg steak;" i. e., finely chopped in a meat cutter and fried. A little onion was added to make the meat palatable to the subject. The eggs were "hard boiled" and were eaten with salt and pepper. The quantity of pepper was too small to take into account in computing the income of organic matter. The dried beef was eaten cold without preparation other than cutting in thin slices. Ordinary creamery butter was used; it was kept in a refrigerator, together with the baked beans, the canned pears, and the milk. The milk was procured fresh each day, as was the bread, which was obtained from a local bakery. Three hundred grams of warm coffee infusion was served with each meal; it was prepared in the usual way.

The following is the daily programme for this experiment, although, owing to lack of experience, it was not followed as closely as in the later experiments:

TABLE 5.—*Daily programme—Metabolism experiment No. 5.*

7.00 a. m	Rise, pass urine, weigh self dressed, collect drip, weigh absorbers.	6.30 p. m	Supper.
7.30 a. m	Breakfast.	7.00 p. m	Pass urine, collect drip, weigh absorbers.
1.00 p. m	Pass urine, collect drip, weigh absorbers.	10.00 p. m	Pass urine, drink water, weigh self dressed, retire.
1.30 p. m	Dinner.	1.00 a. m	Pass urine.
3.30 p. m	Drink water.		

The diary of the subject was begun the second day. It is summarized in Table 6.

TABLE 6.—*Summary of diary—Metabolism experiment No. 5.*

Time.	Weight of subject with clothes.	Pulse rate per minute.	Temperature.	Hygrometer. Dry bulb.	Hygrometer. Wet bulb.
1897.	*Kilograms.*		°*F.*	°*C.*	°*C.*
May 5, 7.00 a. m	69.31	....	....	....	....
5, 7.45 a. m	....	54	97.4	20.5	16.9
5, 10.00 a. m	....	68	97.8	20.3	15.9
5, 12.00 m	....	69	98.8	20.7	16.4
5, 2.00 p. m	....	67	99.0	20.8	16.6
5, 4.00 p. m	....	68	99.6	21.0	16.7
5, 6.00 p. m	....	68	99.6	21.4	16.9
5, 8.50 p. m	....	73	99.2	20.9	17.9
6, 1.00 a. m	....	....	....	20.7	17.2
6, 7.00 a. m	69.09	....	....	....	....
6, 7.10 a. m	....	55	96.2	21.0	16.9
6, 9.30 a. m	....	70	98.0	20.6	16.5
6, 11.30 a. m	....	71	98.9	20.3	16.0
6, 1.30 p. m	....	....	....	20.7	16.8
6, 2.00 p. m	....	77	99.6	....	....
6, 3.30 p. m	....	....	....	20.8	17.2
6, 3.45 p. m	....	73	99.2	....	....
6, 5.10 p. m	69.64	....	....	....	....
6, 5.30 p. m	....	71	99.0	21.0	16.9
6, 7.20 p. m	....	82	99.0	21.0	16.8
6. 10.30 p. m	....	64	98.8	20.8	16.0
7, 1.00 a. m	....	....	....	20.9	16.4
7, 7.10 a. m	69.05	....	....	....	....
7, 7.40 a. m	....	56	96.6	21.1	16.2
7, 10.00 a. m	....	68	98.6	20.8	16.1
7, 12.00 m	....	66	98.8	21.2	16.2
7, 2.00 p. m	....	67	98.9	20.7	16.1
7, 4.00 p. m	....	78	99.2	21.0	16.0
7, 6.00 p. m	69.39	....	....	....	....
7, 6.10 p. m	....	66	99.2	21.2	16.6
7, 8.00 p. m	....	75	99.9	22.2	19.6
7, 10.00 p. m	....	....	....	21.2	18.0
8, 1.00 a. m	....	....	....	20.8	17.0
8, 7.10 a. m	68.82	....	....	....	....
8, 7.20 a. m	....	57	96.8	21.0	16.4

The subject weighed himself on a platform scale sensitive to 10 grams with a weight of 75 kilograms and capable of weighing 100 kilograms. In this experiment the weight of the subject without clothes was not taken. Inasmuch, however, as it was a rest experiment and the subject did not perspire greatly and the clothes were the same at the different weighings, the figures are probably not far out of the way as indications of the changes of body weight. The body temperature was taken by the subject with a registered clinical thermometer.

EXPERIMENTAL DATA OF INCOME.

The experimental data may be divided into two groups—(1) those pertaining to matter and energy of income and (2) the same factors of outgo. The results of the determinations of income are shown in Table 7. These data include the determinations of nitrogen, carbon, hydrogen, and water, and of protein, fats, carbohydrates, and mineral matters in the food. The weights of food materials used each day are shown in the table, and the weights of the different elements and compounds are calculated by means of the figures for the percentage composition shown in Table 3.

TABLE 7.—*Weight, composition, and heats of combustion of foods—Metabolism experiment No. 5.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2782	Beef, fried	120	77.0	34.4	6.6	....	5.51	22.80	3.23	253
2783	Beef, dried	25	15.0	6.1	1.9	....	.98	4.39	.56	51
2781	Eggs	95	70.8	12.0	10.5	....	1.92	14.15	2.17	169
2785	Butter	35	2.8	.4	30.9	....	.06	23.39	3.66	282
2784	Milk	775	661.0	27.9	41.8	38.0	4.50	58.75	8.83	690
2802	Bread, rye	325	143.0	27.9	1.0	148.2	4.45	82.29	11.60	786
2786	Sugar	35	....	....	....	35.0	....	14.74	2.27	139
2780	Beans, baked	125	86.0	9.9	.7	25.8	1.57	16.91	2.33	168
2779	Pears, canned	150	119.3	.5	1.3	28.5	.06	11.47	1.77	117
	Total	....	1,174.9	119.1	94.7	275.5	19.05	248.89	36.42	2,655

EXPERIMENTAL DATA OF OUTGO.

The data of outgo are given in Tables 8 to 12. Table 8 shows the weight of fresh feces and of the elements and compounds determined. These weights are calculated from the figures for percentage of composition shown in Table 3 and the total weight of fresh feces. Inasmuch as the feces from the food of one day can not readily be separated from those of the preceding or following day, we can do nothing else than assume that the undigested residue and metabolic products of which they are composed are essentially uniform from day to day. Even if there were irregularities from day to day, they would hardly be large enough to affect materially the results for each day, nor can they at all affect the average for the whole experiment.

TABLE 8.—*Weight, composition, and heats of combustion of fresh feces—Metabolism experiment No. 5.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2806	Total, 4 days	502	392.6	41.2	22.6	25.6	6.58	55.07	7.38	573
	Average, 1 day	126	98.2	10.3	5.7	6.4	1.65	13.77	1.85	143

Table 9 shows the amount, specific gravity, and percentage composition of the urine in six-hour periods for the time of the experiment and the twenty-four hours subsequent. From these data are calculated the weights of nitrogen, carbon, hydrogen, and water eliminated in the urine. The nitrogen is determined in the fresh urine for each period and also in the composite sample of urine for each day and in the composite sample for the four days of the experiment. It has been assumed that any differences in the quantities of nitrogen as determined in the sample for each six-hour period and in the composite sample for the day would be due rather to small errors of sampling than to errors of analysis. For this reason the figures for the determinations by six-hour periods are used for the computations taken rather than those for the composite for the day or for the whole experiment, where discrepancies occur.

It is hardly practicable to dry samples of fresh urine each day for the determination of carbon, hydrogen, and heats of combustion. Accordingly, a composite sample representing the urine of the four days of each experiment was dried and used for determinations of carbon and hydrogen and heat of combustion. The heat of combustion was also determined in composite samples of the fresh urine each day as explained above, page 23. The precautions taken to avoid error through loss of nitrogen and carbon during the drying of the urine have also been described on page 22.

The data thus obtained show the quantities of nitrogen in the urine for each day and for the four days of the experiment, while those for the quantities of carbon, hydrogen, and water-free substance are obtained for the four days and must be computed for the individual days of the experiment. In making these computations it is assumed that the ratio of nitrogen to carbon, hydrogen, or water free substance will be the same for each individual day as for the four days. Thus the amount of nitrogen in the urine of the first day of this experiment was 20.25 grams, and that for the whole experiment 72.25 grams. The carbon for the whole four days was 46.52 grams. The computations for the amount of carbon in the urine for the first day would then be as follows: 72.25: 46.52:: 20.25: x (=13.04). This method for computing the daily quantities of carbon excreted in the urine differs from that employed in the case of the feces, in which latter the amounts of both nitrogen and carbon were taken as the same from day to day. The reason for this is simple. We know that the quantities of nitrogen and carbon in the urine vary from day to day, and have means for telling approximately the amounts thus excreted. We do not know, nor have we any means for learning exactly how much of the nitrogen, or carbon, or other element of the food for each day is absorbed on that or any other day, but there seems to be good reason for believing that the absorption is nearly uniform from day to day so long as food, exercise, and other conditions remain the same. Even if the last assumption,

namely, the uniform absorption of food in the alimentary canal, is not correct, we have no means whatever for determining the variations and there is nothing else to do but assume the regularity. But we have the actual data for calculating the quantities of nitrogen, carbon, hydrogen, and water-free substance excreted in the urine each day and, making the assumption regarding nitrogen lag mentioned above, the method of calculation here used seems logical.

TABLE 9.—*Amounts and composition of urine—Metabolism experiment No. 5.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.		Carbon.	
1897.		*Grams.*		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*
May 4–5	7 a. m. to 1 p. m	297.8	1.026	1.52	4.53		
	1 p. m. to 7 p. m	871.3	1.011	.77	6.71		
	7 p. m. to 1 a. m	698.9	1.011	.81	5.66		
	1 a. m. to 7 a. m	220.1	1.019	1.52	3.35		
	Total	2,088.1			20.25		13.04
	Total by composite	2,088.1	1.017	.97	20.25		
5–6	7 a. m. to 1 p. m	345.5	1.015	.91	3.14		
	1 p. m. to 7 p. m	795.7	1.011	.75	5.97		
	7 p. m. to 1 a. m	932.9	1.008	.58	5.41		
	1 a. m. to 7 a. m	218.7	1.017	1.32	2.89		
	Total	2,292.8			17.41		11.21
	Total by composite	2,292.8	1.013	.76	17.43		
6–7	7 a. m. to 1 p. m	532.8	1.014	.81	4.32		
	1 p. m. to 7 p. m } 7 p. m. to 1 a. m. }	1,464.5	1.012	.66	9.67		
	1 a. m. to 7 a. m	245.5	1.016	1.29	3.17		
	Total	2,242.8			17.16		11.05
	Total by composite	2,242.8	1.014	.77	17.27		
7–8	7 a. m. to 1 p. m	405.7	1.016	.96	3.89		
	1 p. m. to 7 p. m	727.2	1.010	.65	4.73		
	7 p. m. to 1 a. m	914.0	1.010	.57	5.21		
	1 a. m. to 7 a. m	450.2	1.010	.80	3.60		
	Total	2,497.1			17.43		11.22
	Total by composite	2,497.1	1.011	.70	17.48		
	Total for 4 days, by periods	9,120.8			72.25		
	Composite for 4 days	9,120.8		.79	72.43	0.51	46.52
8–9	7 a. m. to 1 p. m	351.4	1.022	.87	3.06		
	1 p. m. to 7 p. m	250.0	1.027	1.30	3.25		
	7 p. m. to 1 a. m	264.1	1.016	1.09	2.88		
	1 a. m. to 7 a. m	441.6	1.012	1.06	4.68		
	Total	1,307.1			13.87		8.93

TABLE 9.—*Amounts and composition of urine—Metabolism experiment No. 5*—Cont'd.

Date.	Period.	Hydrogen.		Water.		Heats of combustion.	
						Per gram.	Total.
		Per cent.	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
1897.							
May 4-5	7 a. m. to 1 p. m	......	......	......	......	......	......
	1 p. m. to 7 p. m	......	......	......	......	......	......
	7 p. m. to 1 a. m	......	......	......	......	......	......
	1 a. m. to 7 a. m	......	......	......	......	......	......
	Total	......	4.09	......	2,007.3	......	......
	Total by composite	......	......	......	......	.071	148
5-6	7 a. m. to 1 p. m	......	......	......	......	......	......
	1 p. m. to 7 p. m	......	......	......	......	......	......
	7 p. m. to 1 a. m	......	......	......	......	......	......
	1 a. m. to 7 a. m	......	......	......	......	......	......
	Total	......	3.52	......	2,223.4	......	......
	Total by composite	......	......	......	......	.052	119
6-7	7 a. m. to 1 p. m	......	......	......	......	......	......
	1 p. m. to 7 p. m } 7 p. m. to 1 a. m }	......	......	......	......	......	......
	1 a. m. to 7 a. m	......	......	......	......	......	......
	Total	......	3.46	......	2,174.3	......	......
	Total by composite	......	......	......	......	.055	123
7-8	7 a. m. to 1 p. m	......	......	......	......	......	......
	1 p. m. to 7 p. m	......	......	......	......	......	......
	7 p. m. to 1 a. m	......	......	......	......	......	......
	1 a. m. to 7 a. m	......	......	......	......	......	......
	Total	......	3.52	......	2,427.6	......	......
	Total by composite	......	......	......	......	.049	122
	Total for 4 days, by periods	......	......	......	......	......	512
	Composite for 4 days	0.16	14.59	96.84	8,832.6	.056	[1]511
8-9	7 a. m. to 1 p. m	......	......	......	......	......	......
	1 p. m. to 7 p. m	......	......	......	......	......	......
	7 p. m. to 1 a. m	......	......	......	......	......	......
	1 a. m. to 7 a. m	......	......	......	......	......	......
	Total	......	2.79	......	1,251.8	.056	73

[1] Total heat of combustion as determined in dried urine gives 556 calories (see p. 23). As the dried sample did not suffice for a repetition of this determination we have no explanation to offer for the discrepancy between the determinations by the two methods.

The determinations of carbon dioxid and water exhaled by the subject are given in Tables 10 and 11. The methods of calculation are explained by the small letters above the headings of each column. Table 10 shows the amount of air which was drawn through the chamber of the calorimeter during each six-hour period, and the milligrams per liter of carbon dioxid in the incoming air and in the outgoing air. These values are shown in columns *a*, *b*, and *c*. The difference between the last two gives the excess of carbon dioxid in the outgoing air current,

which, multiplied by the total number of liters of air in the ventilating current gives the total weight of carbon dioxid exhaled, as shown in column *e*. Column *f* shows the weight of carbon in the carbon dioxid exhaled. In Table 11 are similar data for the water given off by the subject. The plan of this table differs from that of Table 10 in that the major part of the water is condensed in the freezers. The amount not so condensed is determined the same way as the total amount of carbon dioxid exhaled and is shown in column *d*, while column *f* gives the total amount of water exhaled.

TABLE 10.—*Record of carbon dioxid in ventilating air current—Metabolism experiment No. 5.*

Date.	Period.	(*a*) Volume of ventilating air current.	Carbon dioxid per liter— (*b*) In incoming air.	(*c*) In outgoing air.	(*d*) Excess in outgoing air (*c*—*b*).	(*e*) Total excess in outgoing air (*d* × *a*).	(*f*) Total weight of carbon exhaled in carbon dioxid (*e* × 3/11).
1897.		*Liters.*	*Mgs.*	*Mgs.*	*Mgs.*	*Grams.*	*Grams.*
May 4–5	7 a. m. to 1 p. m.	25, 936	0. 611	10. 510	9. 899	256. 7	70. 0
	1 p. m. to 7 p. m.	26, 263	. 781	10. 144	9. 363	245. 9	67. 1
	7 p. m. to 1 a. m.	26, 397	. 640	9. 547	8. 907	235. 2	64. 1
	1 a. m. to 7 a. m.	26, 154	. 634	5. 737	5. 103	133. 5	36. 4
	Total	104, 750				871. 3	237. 6
5–6	7 a. m. to 1 p. m.	26, 158	. 671	9. 037	8. 366	218. 8	59. 6
	1 p. m. to 7 p. m.	26, 885	. 816	10. 363	9. 547	256. 7	70. 0
	7 p. m. to 1 a. m.	27, 110	. 620	9. 868	9. 248	250. 7	68. 4
	1 a. m. to 7 a. m.	26, 792	. 709	5. 733	5. 024	134. 5	36. 7
	Total	106, 945				860. 7	234. 7
6–7	7 a. m. to 1 p. m.	26, 426	. 704	8. 781	8. 077	213. 4	58. 2
	1 p. m. to 7 p. m.	26, 861	. 551	9. 358	8. 807	236. 6	64. 5
	7 p. m. to 1 a. m.	27, 273	. 578	8. 761	8. 183	223. 2	60. 9
	1 a. m. to 7 a. m.	26, 100	. 894	5. 833	4. 939	128. 9	35. 1
	Total	106, 660				802. 1	218. 7
7–8	7 a. m. to 1 p. m.	25, 577	. 628	9. 290	8. 662	221. 5	60. 4
	1 p. m. to 7 p. m.	26, 045	. 731	10. 464	9. 733	253. 5	69. 1
	7 p. m. to 1 a. m.	26, 240	. 657	10. 313	9. 656	253. 4	69. 1
	1 a. m. to 7 a. m.	26, 938	. 605	5. 650	5. 045	135. 9	37. 1
	Total	104, 800				864. 3	235. 7
	Total for 4 days	423, 155				3, 398. 4	926. 7

TABLE 11.—*Record of water in ventilating air current—Metabolism experiment No. 5.*

Date.	Period.	(*a*) Volume of ventilating air current.	Water per liter— (*b*) In incoming air.	(*c*) In outgoing air.	(*d*) Excess in outgoing air (*c*—*b*).	(*e*) Total excess in outgoing air (*d* × *a*).	(*f*) Condensed in freezers.	(*g*) Correction for water remaining in chamber.[1]	(*h*) Total water exhaled (*e*+*f*+*g*).
1897.		*Liters.*	*Mgs.*	*Mgs.*	*Mgs.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 4–5	7 a. m. to 1 p. m	25,936	1.171	1.329	0.158	4.1	233.8	....	....
	1 p. m. to 7 p. m	26,263	1.050	1.210	.160	4.2	237.2	194.4	....
	7 p. m. to 1 a. m	26,397	1.038	1.230	.192	5.1	252.1	— 4.8	....
	1 a. m. to 7 a. m	26,154	.874	1.006	.132	3.4	223.6	—71.0	....
	Total	104,750	....	....	....	16.8	946.7	118.6	1,082.1
5–6	7 a. m. to 1 p. m	26,158	1.022	1.118	.096	2.5	220.6	....	....
	1 p. m. to 7 p. m	26,885	.992	1.284	.292	7.8	244.9	56.7	....
	7 p. m. to 1 a. m	27,110	1.011	1.215	.204	5.6	275.2	62.2	....
	1 a. m. to 7 a. m	26,792	.924	1.178	.254	6.8	209.8	50.9	....
	Total	106,945	....	....	....	22.7	950.5	169.8	1,143.0
6–7	7 a. m. to 1 p. m	26,426	1.040	1.212	.172	4.6	222.2	....	....
	1 p. m. to 7 p. m	26,861	.922	1.134	.212	5.7	245.4	26.7	....
	7 p. m. to 1 a. m	27,273	.895	1.115	.220	6.0	227.6	55.9	....
	1 a. m. to 7 a. m	26,100	.786	.941	.155	4.0	196.3	—32.8	....
	Total	106,660	....	....	....	20.3	891.5	49.8	961.6
7–8	7 a. m. to 1 p. m	25,577	.886	1.187	.301	7.7	202.6	....	....
	1 p. m. to 7 p. m	26,045	.898	1.064	.166	4.3	218.0	17.5	....
	7 p. m. to 1 a. m	26,240	.813	1.074	.261	6.9	272.1	28.2	....
	1 a. m. to 7 a. m	26,938	.693	.927	.234	6.3	226.3	63.2	....
	Total	104,800	....	....	....	25.2	919.0	108.9	1,053.1
	Total for 4 days	423,155	....	....	....	85.0	3,707.7	447.1	4,239.8

[1] Upon the surface of the absorbers, see p. 53 under description of experiment No. 6.

The details of the calorimetric measurements in these experiments are far too extensive to be given here. Their nature is explained and illustrations are given in another publication.[1] The fundamental data are given in Table 12. This shows in column *a* the amount of heat measured in calories by the current of water at the average range of temperature of the water currents shown in column *b*. In column *d* this heat is corrected to calories at 20° C., the temperature to which all the measurements are reduced. Columns *e* to *g* show the corrections for the heat capacity of the apparatus and for the temperature of food and dishes. Column *h* shows the quantity of water vaporized in the calorimeter and column *i* gives the amount of heat calculated as having been used to vaporize this water and thus carried out with the

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63.

vapor in the outgoing air current. In these calculations the factor 0.592 is used as representing the latent heat of vaporization of water.[1] Column *k* shows the corrected amounts of heat carried out of the apparatus—i. e., the excess of the amount carried out over that brought in during the period named.

TABLE 12.—*Summary of calorimetric measurements—Metabolism experiment No. 5.*

Date.	Period.	(*a*) Heat measured in terms of C_{t_1} to t_2.	(*b*) Average range in temperature between incoming and outgoing water t_1 to t_2.	(*c*) Mean specific heat of water for range t_1 to t_2.	(*d*) Heat measured in terms of C_{20} $(a \times c)$.	(*e*) Change of temperature of calorimeter.
1897.		*Calories.*	*Degrees.*		*Calories.*	*Degrees.*
May 4–5	7 a. m. to 1 p. m	582.4	4.78–13.99	1.0033	584.3	−0.20
	1 p. m. to 7 p. m	496.1	4.34–14.31	1.0032	497.7	+.65
	7 p. m. to 1 a. m	520.1	4.93–15.63	1.0026	521.5	−.30
	1 a. m. to 7 a. m	265.7	10.36–15.85	1.0016	266.1	−.40
	Total	1,864.3			1,869.6	
5–6	7 a. m. to 1 p. m	522.7	3.30–14.26	1.0036	524.6	+.40
	1 p. m. to 7 p. m	557.1	3.24–14.80	1.0035	559.1	+.75
	7 p. m. to 1 a. m	528.6	4.59–16.07	1.0030	530.2	−1.20
	1 a. m. to 7 a. m	318.2	6.91–15.21	1.0026	319.0	−.20
	Total	1,926.6			1,932.9	
6–7	7 a. m. to 1 p. m	489.0	3.90–14.34	1.0035	490.7	+.35
	1 p. m. to 7 p. m	537.6	3.57–14.42	1.0036	539.5	+.80
	7 p. m. to 1 a. m	494.3	4.19–14.93	1.0033	495.9	−.70
	1 a. m. to 7 a. m	309.4	9.02–15.82	1.0020	310.0	−.30
	Total	1,830.3			1,836.1	
7–8	7 a. m. to 1 p. m	483.4	3.13–15.51	1.0035	485.1	+.70
	1 p. m. to 7 p. m	513.4	3.21–16.59	1.0033	515.1	+.30
	7 p. m. to 1 a. m	514.8	4.46–16.68	1.0028	516.2	−.55
	1 a. m. to 7 a. m	284.4	10.67–17.26	1.0014	284.8	−.05
	Total	1,796.0			1,801.2	
	Total for 4 days	7,417.2			7,439.8	

[1] For a discussion of this value, see U. S. Dept. Agr., Office of Experiment Stations Bul. 63, p. 57.

TABLE 12.—*Summary of calorimetric measurements—Metabolism experiment No. 5*—Continued.

Date.	Period.	(*f*) Capacity correction of calorimeter ($e \times 60$).	(*g*) Correction due to temperature of food and dishes.	(*h*) Water vaporized, equals total amount exhaled less amount condensed in chamber.	(*i*) Heat used in vaporization of water ($h \times .592$).	(*k*). Total heat determined ($d+f+g+i$).
1897.		*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
May 4-5	7 a. m. to 1 p. m.	—12	— 21.3	237.9	140.8	691.8
	1 p. m. to 7 p. m.	+39	— 17.5	241.4	142.9	662.1
	7 p. m. to 1 a. m.	—18	— 10.6	257.2	152.3	645.2
	1 a. m. to 7 a. m.	—24	....	227.0	134.4	376.5
	Total	—15	— 49.4	963.5	570.4	2,375.6
5-6	7 a. m. to 1 p. m.	+24	— 20.3	223.1	132.1	660.4
	1 p. m. to 7 p. m.	+45	— 9.6	252.7	149.6	744.1
	7 p. m. to 1 a. m.	—72	— 12.5	280.8	166.2	611.9
	1 a. m. to 7 a. m.	—12	....	216.6	128.2	435.2
	Total	—15	— 42.4	973.2	576.1	2,451.6
6-7	7 a. m. to 1 p. m.	+21	— 13.6	226.8	134.3	632.4
	1 p. m. to 7 p. m.	+48	— 14.7	251.1	148.6	721.4
	7 p. m. to 1 a. m.	—42	— 13.8	233.6	138.3	578.4
	1 a. m. to 7 a. m.	—18	....	200.3	118.6	410.6
	Total	+ 9	— 42.1	911.8	539.8	2,342.8
7-8	7 a. m. to 1 p. m.	+42	— 17.8	210.3	124.5	633.8
	1 p. m. to 7 p. m.	+18	— 4.9	222.3	131.6	659.8
	7 p. m. to 1 a. m.	—33	— 15.3	279.0	165.2	633.1
	1 a. m. to 7 a. m.	— 3	....	232.6	137.7	419.5
	Total	+24	— 38.0	944.2	559.0	2,346.2
	Total for 4 days	+ 3	—171.9	3,792.7	2,245.3	9,516.2

COMPUTED DATA OF INCOME AND OUTGO.

From the experimental data just recorded the income and outgo of nitrogen, carbon, and hydrogen, protein, fat, and energy are computed. Table 13 shows the computed income and outgo of nitrogen and carbon in metabolism experiment No. 5. The values in columns *a*, *b*, and *c* are taken from Tables 7, 8, and 9, respectively.

The quantities in column *d* represent the gain or loss of nitrogen for each day and for the whole experiment. Since the subject had been upon the same diet for four days previous to the commencement of the experiment, it was to be expected that he would be in approximate nitrogen equilibrium. This expectation was realized, as the figures show. There was a slight loss of nitrogen, 2.8 grams, the first day; the remaining three days there was almost exact equilibrium. We find it often the case that the loss of nitrogen is greater or the gain less on the first than on the succeeding days. Assuming that the nitrogen lag is short, this

may perhaps be connected with the slight mental excitement which accompanies the accommodating of the subject to the conditions of life in the chamber. The average for the four days shows a loss of 0.7 of a gram of nitrogen per day.

The data for income and outgo of carbon are likewise obtained from previous tables, and the values in column *k* show the computed loss of carbon for each day and during the whole experiment. It will be seen that the subject was nearly in carbon as well as nitrogen equilibrium.

TABLE 13.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 5.*

Date.	Period.	Nitrogen.				Carbon.				
		(*a*) In food.	(*b*) In feces.	(*c*) In urine.	(*d*) Gain (+) or loss (—) $a-(b+c)$.	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*k*) Gain (+) or loss (—) $e-(f+g+h)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 4–5	7 a. m. to 7 a. m.	19.1	1.6	20.3	—2.8	248.9	13.8	13.0	237.6	—15.5
5–6	.....do..........	19.0	1.7	17.4	— .1	248.9	13.7	11.2	234.7	—10.7
6–7	.....do..........	19.1	1.6	17.2	+ .3	248.9	13.8	11.1	218.8	+ 5.2
7–8	.....do..........	19.0	1.7	17.4	— .1	248.9	13.8	11.2	235.7	—11.8
	Total, 4 days...	76.2	6.6	72.3	—2.7	995.6	55.1	46.5	926.8	—32.8
	Average, 1 day.	19.1	1.7	18.1	— .7	248.9	13.8	11.6	231.7	— 8.2

In this experiment the subject was allowed drinking water whenever and in such quantities as he desired. The coffee infusion, as already stated, contained practically no nitrogen, the amount per liter being found by analysis to be less than 0.05 gram. This quantity, amounting to less than 0.2 gram of nitrogen for the whole experiment, has been ignored, and the coffee infusion has been considered simply as so much water. The amounts of coffee infusion and of water consumed on the different days of this experiment are as follows:

Record of water and coffee consumed—Metabolism experiment No. 5.

Date.	Coffee infusion.	Water.	Total drink.
	Grams.	*Grams.*	*Grams.*
May 4	862.3	870.6	1,732.9
5	897.6	849.8	1,747.4
6	896.9	665.0	1,561.9
7	894.5	977.6	1,872.1
Total	3,551.3	3,363.0	6,914.3

At each meal a vessel containing 300 grams of unsweetened coffee infusion was passed in to the subject. The amount actually consumed depended upon the carefulness with which the vessel was drained. It

was determined by weighing the vessel when it was passed in and when it was taken out, the difference between these weights being the amount consumed.

In Table 14 the income and outgo of water and hydrogen are computed. Column *a* shows the amount of water in the food materials consumed each day, and column *b* the amount consumed as drink, either as water or in the form of coffee. The values in columns *c*, *d*, and *e* are taken from previous tables and serve in the calculations of the apparent loss of water shown in column *f*. The quantities in this column are always negative, since the water given off in the respiratory products is derived not only from water taken into the system in food and drink, but also from the oxidation of hydrogen of organic compounds. The quantities in column *g*, *h*, and *i* represent the amounts of hydrogen in organic combination in the food, feces, and urine, and the values in column *l* show the apparent gains of hydrogen. The quantities in this column are always positive, owing to the fact that the most of the hydrogen in organic combination in the food is eliminated, not in organic combination in the feces and urine, but in the form of water in the urine or respiratory products. The gain or loss of hydrogen for the experiment is calculated by adding together the hydrogen apparently lost as water (column *f*) and the hydrogen in organic combination apparently gained (column *l*). This total gain or loss of hydrogen is shown in column *n*. There was thus a small calculated loss of hydrogen during the experiment, which would correspond to about 185 grams of water per day. These estimates of quantities of hydrogen here and elsewhere in the present bulletin are given for what they are worth. We hope to be able later to study this and other details bearing upon the correction of the estimates.

TABLE 14.—*Income and outgo of water and hydrogen—Metabolism experiment No. 5.*

Date.	Period.	Water.					
		(*a*) In food.	(*b*) In drink.	(*c*) In feces.	(*d*) In urine.	(*e*) In respiratory products.	(*f*) Apparent loss $a+b-(c+d+e)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 4–5	7 a. m. to 7 a. m	1,174.9	1,732.9	98.2	2,007.3	1,082.1	− 279.8
5–6	.....do	1,174.9	1,747.4	98.1	2,223.4	1,143.0	− 542.2
6–7	.....do	1,174.9	1,561.9	98.2	2,174.3	961.6	− 497.3
7–8	.....do	1,174.9	1,872.1	98.1	2,427.6	1,053.1	− 531.8
	Total for 4 days	4,699.6	6,914.3	392.6	8,832.6	4,239.8	−1,851.1
	Average for 1 day	1,174.9	1,728.6	98.2	2,208.2	1,059.9	− 462.8

TABLE 14.—*Income and outgo of water and hydrogen—Metabolism experiment No. 5*—Continued.

Date.	Period.	Hydrogen.					
		(*g*) In food.	(*h*) In feces.	(*i*) In urine.	(*l*) Apparent gain $g-(h+i)$.	(*m*) Loss from water $(f \div 9)$.	(*n*) Total gain (+) or loss (—) $(l+m)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 4–5	7 a. m. to 7 a. m	36.4	1.9	4.1	+ 30.4	— 31.1	— 0.7
5–6	....do	36.4	1.8	3.5	+ 31.1	— 60.2	—29.1
6–7	....do	36.4	1.9	3.5	+ 31.0	— 55.3	—24.3
7–8	....do	36.4	1.8	3.5	+ 31.1	— 59.1	—28.0
	Total for 4 days	145.6	7.4	14.6	+123.6	—205.7	—82.1
	Average for 1 day	36.4	1.9	3.7	+ 30.9	— 51.4	—20.5

In Table 15 are calculations of the gain or loss of protein, fat, and water in this experiment. If nitrogen is gained, a corresponding gain of protein is assumed; if nitrogen is lost, a corresponding loss of protein is likewise assumed. The protein compounds are here assumed to contain, on the average, 16 per cent of nitrogen, 53 per cent of carbon, and 7 per cent of hydrogen. Accordingly the gain or loss of protein is computed by multiplying the gain or loss of nitrogen by 6.25, and is shown in column *b*. Whatever protein is gained or lost must contain certain proportions of carbon and hydrogen, the computed amounts of which are shown in columns *d* and *h*.

TABLE 15.—*Gain or loss of protein* ($N \times 6.25$), *fat, and water—Metabolism experiment No. 5.*

Date.	Period.	(*a*) Nitrogen gained (+) or lost (—).	(*b*) Protein gained (+) or lost (—) $(a \times 6.25)$.	(*c*) Total carbon gained (+) or lost (—).	(*d*) Carbon in protein gained (+) or lost (—) $(b \times .53)$.	(*e*) Carbon in fat, etc., gained (+) or lost (—) $(c-d)$.	(*f*) Fat gained (+) or lost (—) $(e \div .765)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 4–5	7 a. m. to 7 a. m	—2.8	—17.5	—15.5	—9.3	— 6.2	— 8.1
5–6	....do	— .1	— .6	—10.7	— .3	—10.4	—13.6
6–7	....do	+ .3	+ 1.9	+ 5.2	+1.0	+ 4.2	+ 5.5
7–8	....do	— .1	— .6	—11.8	— .3	—11.5	—15.0
	Total for 4 days	—2.7	—16.8	—32.8	—8.9	—23.9	—31.2
	Average for 1 day	— .7	— 4.2	— 8.2	—2.2	— 6.0	— 7.8

TABLE 15.—*Gain or loss of protein ($N \times 6.25$), fat, and water—Metabolism experiment No. 5*—Continued.

Date.	Period.	(*g*) Total hydrogen lost (—).	(*h*) Hydrogen in protein gained (+) or lost (—) ($b \times .07$).	(*i*) Hydrogen in fat gained (+) or lost (—) ($f \times .12$).	(*k*) Hydrogen in water, etc., gained (+) or lost (—) $g-(h+i)$.	(*l*) Water gained (+) or lost (—) ($k \times 9$).
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 4-5	7 a. m. to 7 a. m	— 0.7	—1.2	—1.0	+ 1.5	+ 13.5
5-6	.....do	—29.1	— .1	—1.6	—27.4	—246.6
6-7	.....do	—24.3	+ .1	+ .7	—25.1	—225.9
7-8	.....do	—28.0	.0	—1.8	—26.2	—235.8
	Total for 4 days	—82.1	—1.2	—3.7	—77.2	—694.8
	Average for 1 day	—20.5	— .3	— .9	—19.3	—173.7

Making certain arbitrary assumptions, the total carbon gained or lost less the carbon in protein gained or lost gives the amount of carbon gained or lost in the form of fat. It is probable that the amount of glycogen in the body at the time of rising, 7 a. m., is nearly the same from day to day, so that this assumption probably involves no serious error. It is assumed that average body fat contains 76.5 per cent of carbon, and the amount of fat gained or lost is consequently computed by dividing the carbon gained or lost in fat by .765, as shown in column *f*. Assuming that fat contains 12 per cent of hydrogen, the amount of hydrogen gained or lost in the form of fat is computed and results are given in column *i*. The difference between the total hydrogen gained or lost and that in the protein and fat gained or lost is here taken as representing the hydrogen gained or lost in the form of water. The gains and losses of hydrogen and water as thus calculated are shown in columns *k* and *l* of the table.

So far from saying that these assumptions and the calculations based upon them are correct, we are persuaded that they must be more or less erroneous. To us one of the principal points of interest in connection with the calculations of the amount of water gained or lost is that they emphasize so clearly the uncertainties of this method of calculation and the need of direct determinations of oxygen, sulphur, and other elements of both income and outgo. Even with this complete balance of income and outgo of elements there would still remain a number of uncertainties, as, for instance, the amounts of material in the alimentary canal and the amount of oxygen stored in the organism at different times and under apparently like conditions.[1]

[1] Discussion of the methods of computing the different factors of income and outgo of matter and energy is reserved for a future publication. See page 112.

Table 16 shows the computed income and outgo of energy in this experiment.

TABLE 16.—*Income and outgo of energy—Metabolism experiment No. 5.*

Date.	Period.	(*a*) Heat of combustion of food eaten.	(*b*) Heat of combustion of feces.	(*c*) Heat of combustion of urine.	(*d*) Estimated heat of combustion of protein gained (+) or lost (—).	(*e*) Estimated heat of combustion of fat gained (+) or lost (—).	(*f*) Estimated energy of material oxidized in the body, $a-(b+c+d+e)$.	(*g*) Heat determined.	(*h*) Heat determined greater (+) or less (—) than estimated $(f-g)$.	(*i*) Heat determined greater (+) or less (—) than estimated $(h \div f)$.
1897.		*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
May 4-5	7 a. m. to 7 a. m.	2, 655	143	148	—101	— 76	2, 541	2, 376	—165	—6. 5
5-6	.....do..........	2, 655	143	119	— 3	—128	2, 524	2, 451	— 73	—2. 9
6-7	.....do..........	2, 655	143	123	+ 11	+ 52	2, 326	2, 343	+ 17	+ .7
7-8	.....do..........	2, 655	143	122	— 4	—141	2, 535	2, 346	—189	—7. 5
	Total, 4 days...	10, 620	572	512	— 97	—293	9, 926	9, 516	—410	—4. 1
	Average, 1 day.	2, 655	143	128	— 24	— 73	2, 482	2, 379	—103	—4. 1

Columns *a*, *b*, and *c* of the table represent the heats of combustion of the food, feces, and urine as taken from Tables 7, 8, and 9, respectively. If the body remains in exact nitrogen and carbon equilibrium the difference between the heat of combustion of the food eaten and the sum of that of the urine and feces will, in accordance with the above assumptions, be taken as representing the heat of combustion of the material actually oxidized in the body. If, however, the body gains or loses either protein or fat, it will have a correspondingly larger or smaller store of energy. In this experiment the subject lost both protein and fat, and the energy of this protein and fat was used by the body in addition to that of the food eaten. Inasmuch as the heat of combustion of the body material thus consumed can not be determined directly, it must be assumed from the average heat of combustion of ordinary body protein and body fat. The heat of combustion of 1 gram of protein is taken as 5.75[1] calories and that of fat 9.4 calories per gram. The estimated energy of materials actually oxidized in the body is found by subtracting from the heat of combustion of the food eaten the sum of that of the urine, feces, and protein and fat gained by the body. This is done in calculating the values given in column *f*. It is to be noted that as the protein and fat are lost, the corresponding values used in the calculations are negative. In column *g* in the table

[1] In the previous publication above referred to, U. S. Dept. Agr., Office of Experiment Stations Bul. 63, the factor 5.5 was used, but 5.75 seems to be more nearly correct. Considerable attention has been given to the study of the heats of combustion of food materials and excretory products in this laboratory, but the results of the investigation have not yet been published.

the heat actually determined—i. e., the amount measured (see Table 12)—is given for comparison. Taking the estimated energy of material actually oxidized in the body as 100, the amount of heat given off from the body and measured is 95.9; that is to say, in this experiment there is a discrepancy of 4.1 per cent between the theoretical energy of income and the measured energy of outgo.

A discrepancy of this size makes the experiments unsatisfactory. It is to be considered, however, that this is the first experiment made with the apparatus after it had reached a stage of development which seemed to warrant its use as a calorimeter. The experiments are complicated and the possibilities of error numerous. It is not unusual, in the development of apparatus and methods even for the simpler quantitative determinations in the laboratory, that the first results are inaccurate. The sources of error have to be discovered and the proper methods of manipulation learned by experience before accurate and reliable results are obtained. It is not strange that with an apparatus and methods as complicated as these, and with the sources of physiological error and uncertainty superadded to those of chemical and physical manipulation, the results of the earlier experiments should be more or less erroneous. This particular subject will be referred to later. It will be seen that, as the sources of error revealed by experience have been at least partially eliminated in the later experiments, the agreement of estimated income and measured outgo of energy is reasonably close.

DETAILS OF METABOLISM EXPERIMENT NO. 6.

In this experiment the subject was engaged in active muscular work. This was accomplished by a stationary bicycle connected with a small dynamo. The energy of the external muscular work done was assumed to be entirely transformed into heat within the chamber. The larger part was first transformed into electrical energy by the dynamo which was belted to the wheel of the bicycle, and was then transformed into heat by an electric lamp through which the current passed. A small portion was transformed into heat by the friction of the bicycle dynamo. The latter thus served as an ergometer. The heat thus produced was measured with that given off from the body. The exercise was continued for about eight hours per day, and the heat equivalent of the external muscular work was estimated to be not far from 250 calories per day. The measurements of electrical friction and external muscular work were not as accurate as desirable, so a special ergometer is now being constructed for this purpose. A cyclometer was attached to the bicycle in such a way as to show the number of miles that would have been traveled with the same number of revolutions of the pedals in ordinary riding.

The results of this experiment are summarized and some of the details

are given in the preceding bulletin of this series,[1] to which reference may be made for details not repeated here.

The subject entered the apparatus on the evening of May 17, 1897, and the experiment began at 7 a. m. the following day. The menu and routine of the experiment were as follows:

TABLE 17.—*Daily menu—Metabolism experiment No. 6.*

Menu.	Grams.	Menu.	Grams.
BREAKFAST.		DINNER—continued.	
Deviled ham	20	Baked beans	125
Boiled eggs	55	Canned pears	300
Butter	20	Sugar	20
Milk	200	Coffee	290
White bread	150	SUPPER.	
Sugar	15	Deviled ham	30
Coffee	295	Butter	25
DINNER.		Milk	600
Beef, fried	100	White bread	175
Butter	30	Sugar	15
Milk	50	Coffee	295
White bread	125		

TABLE 18.—*Daily programme—Metabolism experiment No. 6.*

7.00 a. m.	Rise, pass urine; collect drip, weigh shields and absorbers; weigh self, stripped and dressed.	1.50 p. m.	Begin work.
7.45 a. m.	Breakfast; weigh self.	3.50 p. m.	Rest ten minutes, weigh self, drink 200 grams water.
8.20 a. m.	Begin work.	6.00 p. m.	Stop work; weigh self.
10.20 a. m.	Rest ten minutes, weigh self, drink 200 grams water.	6.30 p. m.	Supper; change underclothes; weigh self, stripped and dressed.
12.30 p. m.	Stop work.	7.00 p. m.	Pass urine, collect drip; weigh shields and absorbers.
1.00 p. m.	Pass urine, weigh self, collect drip; weigh shields and absorbers.	10.00 p. m.	Weigh self, drink 200 grams water, retire.
1.15 p. m.	Dinner; weigh self, drink 200 grams water.	1.00 a. m.	Pass urine.

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63, pp. 74–85.

Table 19 summarizes the observations made and recorded by the subject in the chamber during the experiment.

TABLE 19.—*Summary of diary—Metabolism experiment No. 6.*

Time.	Weight of subject. Without clothes.	Weight of subject. With clothes.	Pulse rate per minute.	Temperature.	Cyclometer reading.	Hygrometer. Dry bulb.	Hygrometer. Wet bulb.
1897.	*Kilograms.*	*Kilograms.*		*°F.*	*Miles.*	*°C.*	*°C.*
May 18, 7.00 a. m	66.19	70.22	60	97.0		22.0	18.2
18, 8.15 a. m		70.61					
18, 8.20 a. m					323.0		
18, 10.20 a. m					337.0		
18, 10.25 a. m		70.29	68	98.8		21.9	18.6
18, 12.35 p. m					351.0	22.2	19.8
18, 1.30 p. m		70.54					
18, 3.55 p. m					364.0		
18, 6.05 p. m					376.5		
18, 7.00 p. m	66.40	70.37					
18, 7.30 p. m			80	98.9		22.5	21.0
18, 10.20 p. m		70.25	78	98.4		22.5	19.6
19, 7.00 a. m	65.59	69.43	59	96.4		22.0	18.8
19, 8.20 a. m		70.25					
19, 8.30 a. m					377.0		
19, 10 30 a. m					390.0		
19, 10.40 a. m		70.00				21.4	18.5
19, 12.25 p. m		69.43	77	99.0	401.5	22.2	19.2
19, 1.40 p. m		70.49					
19, 3.50 p. m		70.11			415.0		
19, 6.00 p.m		69.54			429.0		
19, 6.15 p. m			88	99.5		21.6	19.2
19, 6.45 p. m	66.65	70.50					
19, 10.10 p. m			66	98.6		28.5	19.4
19, 10.20 p. m		70.01					
20, 7.00 a. m	65.04	69.52	68	96.2		21.9	18.8
20, 8.10 a. m		70.56					
20, 12.35 p. m		69.12	77	98.5	456.0	21.5	19.0
20, 1.20 p. m		70.31					
20, 3.45 p. m		69.92			468.0		
20, 5.55 p. m		69.33	79	99.2	480.0	22.0	19.6
20, 7.30 p. m	66.42	70.29					
20, 10.00 p. m		70.03		98.4		21.6	19.4
21, 1.00 a. m						22.0	19.4
21, 7.00 a. m	64.83	68.64				21.6	18.6
21, 8.00 a. m			61	97.2			
21, 9.05 a. m					483.0		
21, 12.35 p m		69.56			506.0	21.7	19.0
21, 1.40 p. m		70.11					
21, 1.50 p. m					508.0		
21, 3.50 p. m		69.72			521.0		
21, 5.55 p. m		69.45	79	98.9	534.0	21.6	19.0
21, 7.30 p. m	66.49	70.51					
21, 10.00 p. m		70.25	61	97.2		21.5	19.0
22, 7.00 a. m	66.65	69.50	60	96.8		21.9	18.4

The daily income in the food is shown in Table 20. The calculations are made as explained in description of similar table in experiment No. 5.

TABLE 20.—*Weight, composition, and heats of combustion of foods—Metabolism experiment No. 6.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2789	Beef, fried	100	60.3	29.8	8.7	....	4.77	21.28	3.05	242
2788	Ham, deviled	50	21.1	8.3	18.4	....	1.32	18.05	2.46	218
2790	Eggs	54	39.5	7.6	6.1	....	1.21	7.77	1.18	104
2793	Butter	75	7.0	.7	65.5	....	.12	47.12	7.75	597
2799	Milk	850	725.1	25.5	45.9	47.6	4.08	70.30	10.46	795
2803	Bread, white	450	197.6	37.3	7.2	202.5	5.99	114.53	17.32	1,143
2786	Sugar	50	....	....	....	50.0	....	21.05	3.24	198
2791	Beans, baked	125	89.2	9.0	.5	24.0	1.44	15.55	2.16	153
2792	Pears, canned	300	244.2	.9	.6	53.7	.15	21.03	3.54	228
	Total	....	1,384.0	119.1	152.9	377.8	19.08	336.68	51.16	3,678

The records of the amounts and composition of the feces and urine excreted during the four days of the experiment are given in Tables 21 and 22:

TABLE 21.—*Weight, composition, and heats of combustion of fresh feces—Metabolism experiment No. 6.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2808	Total, 4 days	465.0	365.5	37.7	19.1	26.0	6.00	49.48	7.25	555
	Average, 1 day	116.3	91.4	9.4	4.8	6.5	1.50	12.37	1.81	139

TABLE 22.—*Amounts and composition of urine—Metabolism experiment No. 6.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.		Carbon.	
		Grams.		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*
1897.							
May 18-19	7 a. m. to 1 p. m	576.0	1.016	0.95	5.47		
	1 p. m. to 7 p. m	364.8	1.023	1.12	4.09		
	7 p. m. to 1 a. m	263.1	1.027	1.71	4.50		
	1 a. m. to 7 a. m	146.0	1.025	2.13	3.11		
	Total	1,349.9			17.17		13.16
	Total by composite	1,349.9		1.30	17.55		
19-20	7 a. m. to 1 p. m	344.7	1.022	1.30	4.48		
	1 p. m. to 7 p. m	314.6	1.026	1.32	4.15		
	7 p. m. to 1 a. m	338.1	1.023	1.64	5.54		
	1 a. m. to 7 a. m	112.0	1.026	1.98	2.22		
	Total	1,109.4			16.39		12.56
	Total by composite	1,109.4		1.47	16.30		
20-21	7 a. m. to 1 p. m	240.8	1.022	1.11	2.67		
	1 p. m. to 7 p. m	323.7	1.026	1.32	4.27		
	7 p. m. to 1 a. m	309.1	1.025	1.66	5.13		
	1 a. m. to 7 a. m	160.2	1.025	2.03	3.15		
	Total	1,033.8			15.22		11.66
	Total by composite	1,033.8		1.53	15.82		
21-22	7 a. m. to 1 p. m	357.4	1.024	1.21	4.32		
	1 p. m. to 7 p. m	288.8	1.026	1.30	3.75		
	7 p. m. to 1 a. m	516.3	1.016	1.10	5.68		
	1 a. m. to 7 a. m	142.2	1.025	1.82	2.59		
	Total	1,304.7			16.34		12.52
	Total by composite	1,304.7		1.23	16.05		
	Total for 4 days, by periods	4,797.8			65.12		
	Composite for 4 days	4,797.8		1.34	64.29	1.04	49.90
22-23	7 a. m. to 1 p. m	483.6	1.013	.91	4.40		
	1 p. m. to 7 p. m	300.0	1.020	.92	2.76		
	7 p. m. to 1 a. m	238.3	1.021	1.09	2.60		
	1 a. m. to 7 a. m	180.7	1.025	1.44	2.60		
	Total	1,202.6			12.36		9.45
23	7 a. m. to 1 p. m	244.0		1.22			
	1 p. m. to 7 p. m	187.0		1.22			

TABLE 22.—*Amounts and composition of urine—Metabolism experiment No. 6*—Cont'd.

Date.	Period.	Hydrogen.		Water.		Heats of combustion	
						Per gram.	Total.
1897.		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
May 18-19	7 a. m. to 1 p. m.	....	....	....	....	....	....
	1 p. m. to 7 p. m.	....	....	....	....	....	....
	7 p. m. to 1 a. m.	....	....	....	....	....	....
	1 a. m. to 7 a. m.	....	....	....	....	....	....
	Total	....	4.05	....	1,275.0	....	....
	Total by composite	....	....	....	....	0.094	127
19-20	7 a. m. to 1 p. m.	....	....	....	....	....	....
	1 p. m. to 7 p. m.	....	....	....	....	....	....
	7 p. m. to 1 a. m.	....	....	....	....	....	....
	1 a. m. to 7 a. m.	....	....	....	....	....	....
	Total	....	3.86	....	1,037.9	....	....
	Total by composite	....	....	....	....	.119	132
20-21	7 a. m. to 1 p. m.	....	....	....	....	....	....
	1 p. m. to 7 p. m.	....	....	....	....	....	....
	7 p. m. to 1 a. m.	....	....	....	....	....	....
	1 a. m. to 7 a. m.	....	....	....	....	....	....
	Total	....	3.59	....	967.4	....	....
	Total by composite	....	....	....	....	.115	119
21-22	7 a. m. to 1 p. m.	....	....	....	....	....	....
	1 p. m. to 7 p. m.	....	....	....	....	....	....
	7 p. m. to 1 a. m.	....	....	....	....	....	....
	1 a. m. to 7 a. m.	....	....	....	....	....	....
	Total	....	3.85	....	1,233.5	....	....
	Total by composite	....	....	....	....	.094	123
	Total for 4 days, by periods	....	....	....	....	....	501
	Composite for 4 days	0.32	15.35	94.08	4,513.8	.105	[1] 504
22-23	7 a. m. to 1 p. m.	....	....	....	....	....	....
	1 p. m. to 7 p. m.	....	....	....	....	....	....
	7 p. m. to 1 a. m.	....	....	....	....	....	....
	1 a. m. to 7 a. m.	....	....	....	....	....	....
	Total	....	2.91	....	1,148.8	.085	103
23	7 a. m. to 1 p. m.	....	....	....	....	....	....
	1 p. m. to 7 p. m.	....	....	....	....	....	....

[1] Total heat of combustion as determined in dried urine also gives 504 calories (see p. 23).

It was soon found that when the subject was engaged in active exercise on the bicycle the chamber temperature rose enough to cause some discomfort. To avoid this the outer clothing was removed during the working periods and the subject wore only his underclothes. These were changed each day after the work was done, and the amount of water absorbed by them was determined. In the description of the work, experiments on page 24, it was explained that the underclothing was carefully washed in distilled water, dried, and weighed before being passed into the chamber for use. The underclothes were again weighed as soon as removed from the chamber and the increase in weight recorded as water, the amount of solid material absorbed in the perspiration being regarded as too small to take into account. The clothes were passed into

the chamber before use and taken out after use in a tightly closed copper can, in which they were weighed. The quantity of nitrogen in the products of perspiration was, however, determined by extracting the clothes with distilled water, evaporating and determining the nitrogen in the concentrated residue by the Kjeldahl process as already stated. The quantities of water and nitrogen removed in the underclothes are shown in Table 23.

TABLE 23.—*Water removed from chamber in underclothes—Metabolism experiment No. 6.*

Period.	Date.	Weight of can and clothes.	Gain (water, etc., absorbed).	Remarks.
	1897.	*Grams.*	*Grams.*	
Evening	May 17	1,673.0		
Do	May 18	1,704.0		
			31.0	Contained 0.28 gram nitrogen.
Do	May 18	1,641.5		
Do	May 19	1,664.8		
			23.3	Contained 0.23 gram nitrogen.
Do	May 19	1,606.0		
Do	May 20	1,632.0		
			26.0	Contained 0.20 gram nitrogen.
Do	May 20	1,624.7		
Do	May 21	1,647.0		
			22.3	Contained 0.17 gram nitrogen.
Total	....	....	102.6	

With the large exhalation of water from the body which accompanied the rather intense muscular exertion, the subject required more drinking water than usual. He drank ad libitum on the first day. The amount was recorded and he received the same quantities on each of the succeeding days.

RESIDUAL CARBON DIOXID AND WATER—DRIP WATER, OR DRIP.

These terms, which are used in the descriptions and tables of this and succeeding experiments, demand a word of explanation. The difference between the quantity of carbon dioxid and water in the incoming and that in the outgoing air current for a given period, as six hours, does not represent exactly the amount of carbon dioxid and water imparted to the air in the chamber by the subject during the period, because the quantities remaining in the chamber at the end may not be the same as were there at the beginning of the period. For instance, if a change from rest to work is made during the period the quantities of carbon dioxid and water will be increased, and the air remaining in the chamber at the end of the period will have a larger percentage of these products than was present in the air of the chamber at the beginning. Furthermore, with the increased water content of the air consequent upon the increased muscular work the amount of water accumulated by condensation upon the absorbers and upon and in the shields may be gradually increased. Indeed, the amount of water thus condensed in the periods of active work is apt to be so large that a portion gradually drips from the shields into the "drip flasks"

suspended at the ends of the shields. This last is called drip water, or drip. On the other hand, with a change from work to rest the carbon dioxid and water given off by the subject will be diminished, and the weights of these in the air of the chamber and the weight of water condensed upon the surfaces of the absorbers and shields will be less at the end than at the beginning.

It is therefore necessary to determine the gain or loss of carbon dioxid and water in the air of the chamber and of water on the surfaces of the absorbers and shields during each experimental period in order to learn exactly how much of each is given off by the subject during the period. To this end special samples of the air are drawn from the chamber at the beginning and the end of each period, and the quantities of carbon dioxid and water are determined. If the drip water has accumulated in the flasks it is either passed out of the chamber and weighed or, if the quantity is small, its volume is measured inside the chamber. The system of absorbers and shields is weighed at the beginning, middle, and end of each of the day periods; that is, at 7 a. m., 1 p. m., and 7 p. m. The samples of residual air are drawn by a small aspirator and passed over sulphuric acid and soda-lime as in the determination of these materials in the ventilating air current. The methods employed for taking the samples, determining the carbon dioxid and water, and applying the corrections are described in the publication already referred to.[1]

QUANTITIES OF WATER ADHERING TO THE COPPER WALLS OF THE CHAMBER.

The quantities of water which are condensed upon the inner surface of the copper walls of the calorimeter vary with the amounts in the air of the chamber and the temperature of the latter. A series of special experiments made for the purpose of testing this question has persuaded us that the quantities thus adhering to smooth sheet copper are small and that differences under the conditions of the metabolism experiment are so slight that they would not materially affect the results. The experiments for determining the quantities of water condensed on the surface of copper were made as follows: A rectangular sheet of copper presenting approximately 2 square meters of surface was rolled into the form of a spiral and suspended in a wooden box by a wire which passed through a small hole in the top of the box and was attached to the arm of a balance sensitive to centigrams. By appropriate devices the temperature and water content of the air in the box were caused to vary through ranges similar to those which obtain in the chamber of the calorimeter in different experiments. The sheet of copper was allowed to remain for a considerable time, from twelve to twenty-four hours, in the atmosphere of the box, in order that the water condensed upon its surface might accommodate itself to the condition of moisture and temperature. The differences in weight were assumed to represent differences in the amounts of water condensed upon the surface. The extreme differences found in these experiments amounted

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63, pp. 37, 65.

to less than 3 centigrams per square meter of surface. This would correspond to 0.54 gram for the whole 18 square meters of the inner surface of the chamber.

It seems to us extremely improbable that such variations in the amounts of water condensed upon the whole interior surface of the respiration chamber and air pipes between the points where samples were taken for analysis would be sufficient to affect materially the results of the experiments. It may, however, become necessary to take these variations into account in future efforts to secure more accurate determinations of water and hydrogen, but at present we consider the errors here involved as less than the unavoidable errors in the determinations of water and hydrogen in the food and excretory products.

The results of the measurements of the residual carbon dioxid and water are summarized in the following table:

TABLE 24.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 6.*

Date.	End of period.	Carbon dioxid.		Water.				
		Total amount in chamber.	Gain (+) or loss (—) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (—) over preceding period.	Change in weight of absorbers. Gain (+) or loss (—).	Drip from absorbers.	Total amount gained (+) during the period.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 18-19	7 a.m	34.3	....	63.6	....	....	....	....
	1 p.m	104.2	+69.9	67.3	+3.7	+214	339.7	+ 557.4
	7 p.m	115.6	+11.4	73.9	+6.6	+ 31	688.9	+ 726.5
	1 a.m	63.4	—52.2	73.2	— .7	— 35	134.9	+ 99.0
	7 a.m	33.8	—29.6	63.5	—9.7	— 35	134.9	+ 90.4
	Total	....	— .5	....	— .1	+175	1,298.4	+1,473.3
19-20	1 p.m	110.2	+76.4	68.8	+5.3	+102	343.5	+ 450.8
	7 p.m	106.4	— 3.8	71.8	+3	— 10	566	+ 559.0
	1 a.m	45.8	—60.6	71.5	— .3	— 98.5	139	+ 40.2
	7 a.m	32.4	—13.4	64.6	—6.9	— 98.5	139	+ 33.6
	Total	....	— 1.4	....	+1.1	—105	1,187.5	+1,083.6
20-21	1 p.m	122.9	+90.5	58.6	—6.0	+185	319.6	+ 498.6
	7 p.m	89.1	—33.8	68.4	+9.8	— 45	620.5	+ 585.3
	1 a.m	48.0	—41.1	67.7	— .7	— 38	80.6	+ 41.9
	7 a.m	37.6	—10.4	64.4	—3.3	— 38	80.7	+ 39.4
	Total	....	+ 5.2	....	— .2	+ 64	1,101.4	+1,165.2
21-22	1 p.m	112.2	+74.6	70.2	+5.8	+ 61	190.9	+ 257.7
	7 p.m	79.7	—32.5	63.5	—6.7	+ 49	511.6	+ 553.9
	1 a.m	29.7	—50.0	59.9	—3.6	— 43.5	102.5	+ 55.4
	7 a.m	30.5	+ .8	56.8	—3.1	— 43.5	102.5	+ 55.9
	Total	....	— 7.1	....	—7.6	+ 23	907.5	+ 922.9
	Total for 4 days	....	— 3.8	....	—6.8	+157	4,494.8	+4,645.0

The records of carbon dioxid and water vapor in the ventilating air current have been given in detail in the account of this experiment in the previous publication already referred to.[1] The results in daily periods are summarized in Table 25. These have been corrected for the amounts of residual carbon dioxid and water, drip, etc., and show the total amount of carbon dioxid and water exhaled by the subject during each day of the experiment. For the details by six-hour periods reference may be made to Tables 25 and 27, pages 79 and 81 of Bulletin No. 63.

TABLE 25.—*Summary of carbon dioxid and water in ventilating air current—Metabolism experiment No. 6.*

Date.	Period.	Volume of ventilating air current.	Carbon dioxid. Total excess in outgoing air.	Carbon dioxid. Correction for residual amount in apparatus.	Carbon dioxid. Corrected amount exhaled by subject.	Total weight of carbon exhaled in carbon dioxid.	Water. Total excess in outgoing air.	Water. Condensed in freezers.	Water. Correction for residual amount in chamber.	Water. Total amount exhaled.
1897.		*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 18–19	7 a. m. to 7 a. m.	91,273	1,334.9	−0.5	1,334.4	364.0	29.7	1,080.9	1,473.3	[1]2,583.9
19–20	.....do	94,260	1,255.8	−1.4	1,254.4	342.1	32.5	1,109.3	1,083.6	2,225.4
20–21	.....do	91,958	1,260.5	+5.2	1,265.7	345.1	40.7	1,099.9	1,165.2	2,305.8
21–22	.....do	95,889	1,215.1	−7.1	1,208.0	329.5	25.6	1,125.8	922.9	2,074.3
	Total, 4 days	373,380	5,066.3	−3.8	5,062.5	1,380.7	128.5	4,415.9	4,645.0	9,189.4
	Average, 1 day	93,345			1,265.6	345.2				2,297.4

[1] The value given in Bulletin 63 for the water exhaled was 2,513.4 grams. This did not include 70.5 grams "drip."

The details of the calorimetric observations by six-hour periods are given in Table 29, page 82 of Bulletin No. 63. They are summarized for individual days in Table 26 herewith.

TABLE 26.—*Summary of calorimetric measurements—Metabolism experiment No. 6.*

Date.	Period.	Heat measured.	Change of temperature of calorimeter.	Capacity correction.	Correction due to temperature of food and dishes.	Water vaporized.	Equivalent heat of water vaporized.	Total heat (determined).	Equivalent heat of work done.
1897.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
May 18–19	7 a. m. to 7 a. m.	3,343.8	+0.15	+9	−40.5	1,110.5	657.4	3,969.7	270
19–20	.....do	3,025.2	− .02	−1	−31.7	1,141.8	675.9	3,668.4	230
20–21	.....do	3,091.1	− .13	−8	−47.9	1,140.6	675.2	3,710.4	268
21–22	.....do	2,897.6	+ .11	+7	−29.4	1,151.4	681.6	3,556.8	255
	Total, 4 days	12,357.7				4,544.3	2,690.1	14,905.3	1,023
	Average, 1 day	3,089.4					672.5	3,726.3	256

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63, pp. 79, 81.

Table 27 shows the computed income and outgo of nitrogen and carbon. The methods of calculation are the same as those already described under similar tables in connection with experiment No. 5.

TABLE 27.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 6.*

Date.	Period.	Nitrogen. (a) In food.	Nitrogen. (b) In feces.	Nitrogen. (c) In urine.[1]	Nitrogen. (d) Gain (+) or loss (—) a—(b+c).	Carbon. (e) In food.	Carbon. (f) In feces.	Carbon. (g) In urine.	Carbon. (h) In respiratory products.	Carbon. (k) Gain (+) or loss (—) e—(f+g+h).
1897.		*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
May 18–19	7 a. m. to 7 a. m.	19.1	1.5	17.5	+0.1	336.7	12.4	13.1	364.0	— 52.8
19–20	.....do.........	19.1	1.5	16.6	+1.0	336.7	12.4	12.6	342.1	— 30.4
20–21	.....do.........	19.1	1.5	15.4	+2.2	336.7	12.4	11.7	345.2	— 32.6
21–22	.....do.........	19.1	1.5	16.5	+1.1	336.7	12.4	12.5	329.4	— 17.6
	Total, 4 days...	76.4	6.0	66.0	+4.4	1,346.8	49.6	49.9	1,380.7	—133.4
	Average, 1 day.	19.1	1.5	16.5	+1.1	336.7	12.4	12.5	345.2	— 33.4

[1] Including nitrogen of perspiration (see p. 53).

In this experiment the subject was allowed a definite amount of water each day in addition to the coffee infusion which, as above explained, is here considered as consisting entirely of water. The amounts of coffee infusion and drinking water consumed on different days of this experiment are as follows:

Record of drinking water and coffee—Metabolism experiment No. 6.

Date.	Coffee infusion.	Drinking water.	Total drink.
	Grams.	*Grams.*	*Grams.*
May 18	876.1	800	1,676.1
19	894.7	800	1,694.7
20	886.8	800	1,686.8
21	868.5	800	1,668.5
Total	3,526.1	3,200	6,726.1

The reason for the slight variation from day to day in the amount of coffee is found in the failure of the subject to drain the entire 300 grams served from the vessel containing it. The drinking water was drained much more completely, and the amounts left in the flask in which it was served in this experiment were not sufficient to weigh.

The computed income and outgo of water and hydrogen in experiment No. 6 is shown in Table 28:

TABLE 28.—*Income and outgo of water and hydrogen—Metabolism experiment No. 6.*

Date.	Period.	Water. (a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.[1]	(f) Apparent loss, $a+b-(c+d+e)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 18–19	7 a. m. to 7 a. m	1,384.0	1,676.1	91.4	1,275.0	2,614.9	— 921.2
19–20	.....do	1,384.0	1,694.7	91.4	1,037.9	2,248.7	— 299.3
20–21	.....do	1,384.0	1,686.8	91.4	967.4	2,331.8	— 319.8
21–22	.....do	1,384.0	1,668.5	91.4	1,233.5	2,096.6	— 369.0
	Total, 4 days	5,536.0	6,726.1	365.6	4,513.8	9,292.0	—1,909.3
	Average, 1 day	1,384.0	1,681.5	91.4	1,128.4	2,323.0	— 477.3

Date.	Period.	Hydrogen. (g) In food.	(h) In feces.	(i) In urine.	(l) Apparent gain, $g-(h+i)$.	(m) Loss from water $(f\div 9)$.	(n) Total gain (+) or loss (—) $(l+m)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 18–19	7 a. m. to 7 a. m	51.2	1.8	4.0	+ 45.4	—102.4	—57.0
19–20	.....do	51.1	1.8	3.9	+ 45.4	— 33.3	+12.1
20–21	.....do	51.2	1.8	3.6	+ 45.8	— 35.5	+10.3
21–22	.....do	51.1	1.8	3.9	+ 45.4	— 41.0	+ 4.4
	Total, 4 days	204.6	7.2	15.4	+182.0	—212.2	—30.2
	Average, 1 day	51.2	1.8	3.9	+ 45.5	— 53.0	— 7.5

[1] Including water in perspiration (see p. 53).

The gain or loss of protein, fat, and water in experiment No. 6, computed as in the previous experiment, is shown in Table 29:

TABLE 29.—*Gain or loss of protein ($N \times 6.25$), fat, and water—Metabolism experiment No. 6.*

Date.	Period.	(a) Nitrogen gained (+) or lost (—).	(b) Protein gained (+) or lost (—) ($a \times 6.25$).	(c) Total carbon gained (+) or lost (—).	(d) Carbon in protein gained (+) or lost (—) ($b \times .53$).	(e) Carbon in fat, etc., gained (+) or lost (—) ($c - d$).	(f) Fat gained (+) or lost (—) ($e \div .765$).
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 18–19	7 a. m. to 7 a. m	+0.1	+ 0.6	— 52.8	+ 0.3	— 53.1	— 69.4
19–20	.....do	+1.0	+ 6.3	— 30.4	+ 3.3	— 33.7	— 44.1
20–21	.....do	+2.2	+13.7	— 32.6	+ 7.3	— 39.9	— 52.2
21–22	.....do	+1.1	+ 6.9	— 17.6	+ 3.7	— 21.3	— 27.8
	Total, 4 days	+4.4	+27.5	—133.4	+14.6	—148.0	—193.5
	Average, 1 day	+1.1	+ 6.9	— 33.4	+ 3.6	— 37.0	— 48.4

Date.	Period.	(g) Total hydrogen gained (+) or lost (—).	(h) Hydrogen in protein gained (+) or lost (—) ($b \times .07$).	(i) Hydrogen in fat gained (+) or lost (—) ($f \times .12$).	(k) Hydrogen in water, etc., gained (+) or lost (—) $g-(h+i)$.	(l) Water gained (+) or lost (—) ($k \times 9$).
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 18–19	7 a. m. to 7 a. m	—57.0	+0.1	— 8.3	—48.8	—439.2
19–20	.... do	+12.1	+0.4	— 5.3	+17.0	+153.0
20–21	.....do	+10.3	+0.9	— 6.3	+15.7	+141.3
21–22	.....do	+ 4.4	+0.5	— 3.3	+ 7.2	+ 64.8
	Total, 4 days	—30.2	+1.9	—23.2	— 8.9	— 80.1
	Average, 1 day	— 7.5	+ .5	— 5.8	— 2.2	— 20.0

The computed income and outgo of energy is given in the following table:

TABLE 30.—*Income and outgo of energy—Metabolism experiment No. 6.*

Date.	Period.	(*a*) Heat of combustion of food eaten.	(*b*) Heat of combustion of feces.	(*c*) Heat of combustion of urine.	(*d*) Estimated heat of combustion of protein gained (+) or lost (—).	(*e*) Estimated heat of combustion of fat gained (+) or lost (—).	(*f*) Estimated energy of material oxidized in the body, *a*—(*b*+*c*+*d*+*e*).	(*g*) Heat determined.	(*h*) Heat determined greater (+) or less (—) than estimated (*f*—*g*).	(*i*) Heat determined greater (+) or less (—) than estimated (*h*÷*f*).
1897.		*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
May 18–19	7 a. m. to 7 a. m.	3,678	139	127	+ 4	— 652	4,060	3,970	— 90	—2.2
19–20	.... do.........	3,678	139	132	+ 36	— 415	3,786	3,668	—118	—3.1
20–21	.....do.........	3,678	139	119	+ 78	— 491	3,833	3,710	—123	—3.2
21–22	.....do.........	3,678	139	123	+ 40	— 261	3,637	3,557	— 80	—2.2
	Total, 4 days..	14,712	556	501	+158	—1,819	15,316	14,905	—411	—2.7
	Average, 1 day	3,678	139	125	+ 40	— 455	3,829	3,726	....	....

The theoretical income of energy in this experiment averaged 3,829 calories per day and the measured outgo 3,726, or 97.3 per cent of the theoretical income, thus making a discrepancy of 2.7 per cent. While this agreement is closer than that found in the preceding experiment, it is still far from satisfactory. There are various errors of experiment which may serve in part to account for the discrepancy. One, the sampling of food materials, has already been referred to and appears in the preceding and in the two following experiments, as well as in this experiment—that is, in the first four of the series. One source of uncertainty in this experiment, however, was due to the muscular work performed by the subject, which was at times rather severe. Heat was developed within the apparatus at a rapid rate, and the changes in temperature inside the chamber were considerable. We are inclined to think that the heat measurements under these circumstances were less accurate than usual, and that minor modifications in apparatus and manipulation, which have been provided for in later experiments, have helped and will help to diminish them.

DETAILS OF METABOLISM EXPERIMENT NO. 7.

This was a so-called alcohol experiment. The object is outlined on page 6. A portion of the usual diet was replaced by an isodynamic quantity of ethyl alcohol. The diet furnished 104 grams of protein and somewhat less than 2,000 calories of energy aside from that in the alcohol which it was calculated would furnish a little over 500 calories of energy per day. The subject was "at rest;" that is to say, he had

as little muscular exercise as was consistent with convenience and comfort. The total amount of protein and energy in the diet was such as had been found sufficient to maintain the body nearly in nitrogen and carbon equilibrium. Opportunity was thus given to test the completeness of the oxidation of the alcohol in the body, the agreement of the amount of kinetic energy produced by such oxidation with the potential energy of the same amount of alcohol as measured by its heat of combustion in the bomb calorimeter, and also the action of the alcohol in protecting protein and fat from oxidation. The usual preliminary period of four days was spent outside the chamber with the same diet as in the experiment proper.

The subject entered the chamber on the evening of June 7, 1897. The experiment proper began at 7 a. m. the following morning. The subject spent the time not required for the routine observations called for by the daily programme in reading, writing, and sleeping. The alcohol was administered in the form of high-grade commercial spirits containing 90.6 per cent of ethyl hydroxid, as it was thought desirable in this case to test the effect of ethyl alcohol as such rather than in the form of whisky, brandy, or other ordinary alcoholic beverage. The amount was such as to furnish 72.5 grams of ethyl hydroxid per day. To this amount of alcohol and 45 grams of sugar were added an amount of coffee infusion sufficient to make 1,000 grams per day. The alcohol was thus administered in six doses, three larger ones with the meals and three smaller between meals. The proportions at the different times were: With breakfast, 150 cubic centimeters (11.5 grams alcohol); at 10.30 a. m., 100 cubic centimeters (7.6 grams alcohol); for dinner, 250 cubic centimeters (19.1 grams alcohol); at 3.30 p. m., 100 cubic centimeters (7.6 grams alcohol); at supper, 250 cubic centimeters (19.1 grams alcohol); before retiring, the remainder (not far from 100 cubic centimeters, containing 7.6 grams alcohol). The quantities of alcohol were not large as compared with those which moderate drinkers are accustomed to consume. The total amount, 72.5 grams, or 2½ ounces, is about as much as would be contained in a bottle of ordinary Rhine wine or claret with 10 per cent absolute alcohol and a little less than would be furnished in three ordinary glasses of whisky each containing 2 ounces of 45 per cent alcohol.[1] The reason for taking the alcohol in these small doses was to avoid appreciable effect upon the nerves, as the purpose was to get light upon the action of alcohol under normal bodily conditions. As will be seen from Table 33, the pulse and body temperature did not differ materially from those of other experiments and the subject was not conscious of any mental or physical disturbance or other special effect of the alcohol except possibly a slight sense of dullness at times. The subject was a Swede, and had come to this country after reaching maturity. He had been accustomed from boyhood to occasional use of malt and distilled

[1] See computations in The Century Magazine, May, 1888, pp. 138, 139.

liquors, but of late years had partaken of these but seldom and in small quantities. During the time of these experiments, including the periods which preceded and followed those with alcohol, he took no spirituous liquor except that administered in the alcohol experiments. This he did in accordance with a special arrangement by which he became a total abstainer except at the times and for the purpose of these experiments.

The menu, daily programme, summary of the diary, and experimental and computed data of income and outgo are given in Tables 31–41. The explanations which accompany the tables of experiments Nos. 5 and 6 apply to those of experiment No. 7. But in addition to the usual data of outgo there were in this experiment determinations of alcohol eliminated as such in the urine and in the respiratory products. These determinations are shown in Table 41.

TABLE 31.—*Daily menu—Metabolism experiment No. 7.*

Menu.	Grams.	Menu.	Grams.
BREAKFAST.		DINNER—continued.	
Boiled eggs	140	Baked beans	125
Butter	5	Canned pears	150
Milk	50	Coffee and alcohol	250
Rye bread	30	SUPPER.	
Coffee and alcohol	150	Dried beef	25
DINNER.		Butter	5
Beef, fried	170	Milk	525
Butter	5	Rye bread	75
Rye bread	45	Coffee and alcohol	250

Besides the coffee and alcohol consumed at the regular meals, 100 grams was consumed in the middle of the forenoon, 100 grams in the middle of the afternoon, and the remainder—about 100 grams—just before retiring.

TABLE 32.—*Daily programme—Metabolism experiment No. 7.*

7.00 a. m.	Rise, pass urine, weigh self stripped and dressed, collect drip, weigh absorbers.	6.30 p. m.	Supper.
7.50 a. m.	Breakfast.	7.00 p. m.	Pass urine, weigh self stripped and dressed, collect drip, weigh absorbers.
10.00 a. m.	Drink alcohol.	9.00 p. m.	Drink remainder of alcohol.
1.00 p. m.	Pass urine, collect drip, weigh absorbers.	10.00 p. m.	Drink 300 grams water, weigh self dressed.
1.30 p. m.	Dinner, 200 grams water	1.00 a. m.	Pass urine.
3.30 p. m.	Drink alcohol.		

TABLE 33.—*Summary of diary—Metabolism experiment No. 7.*

Time.	Weight of subject. Without clothes.	With clothes.	Pulse rate per minute.	Temperature.	Hygrometer. Dry bulb.	Wet bulb.
1897.	*Kilograms.*	*Kilograms.*		° F.	° C.	° C.
June 8, 7.00 a. m	66.68	70.74	63	95.7	22.0	18.2
8, 9.00 a. m			67	98.8	21.5	17.6
8, 11.00 a. m			59	98.6	21.5	17.4
8, 1.00 p. m		70.52	58	98.6	21.8	17.9
8, 3.30 p. m			61	98.2	21.6	18.0
8, 5.30 p. m			60	98.0	21.5	17.8
8, 7.00 p. m	67.50	71.48				
8, 7.30 p. m			70	99.0	21.8	18.2
8, 9.30 p. m			56	98.0	21.9	18.6
8, 10 00 p. m		71.40				
9, 1.00 a. m			60	97.2	22.4	20.0
9, 7.00 a. m	66.70	70.71	60	96.2	22.2	19.0
9, 9.00 a. m			75	98.8	21.5	17.6
9, 11.00 a. m			71	98.4	21.5	17.8
9, 1.00 p. m		70.22	67	99.4	21.7	18.0
9, 3.00 p. m			68	99.2	21.8	18.6
9, 5.00 p. m			67	99.0	21.6	18.4
9, 6.30 p. m			80	99.6	21.8	18.6
9, 7.00 p. m	66.88	70.82				
9, 9.00 p. m			65	99.0	21.5	18.8
9, 9.45 p. m		70.71				
10, 1.00 a. m			62	98.0	21.8	19.6
10, 7.00 a. m	65.80	69.79				
10, 7.30 a. m			56	96.7	21.7	17.8
10, 9.50 a. m			74	97.8	21.8	17.8
10, 11.30 a. m			75	99.0	21.6	17.8
10, 1.00 p. m		69.93				
10, 1.35 p. m			77	98.9	21.6	17.8
10, 3.30 p. m			71	99.2	21.8	18.4
10, 5.30 p. m			70	99.3	21.5	17.8
10, 7.00 p. m	66.76	70.77				
10, 7.30 p. m			82	100.0	21.7	18.7
10, 9.30 p. m			68	98.7	21.5	18.8
10, 10.00 p. m		70.40				
11, 1.00 a. m			68	97.4	22.0	19.1
11, 7.00 a. m	65.87	69.90				
11, 7.30 a. m			59	96.1	21.5	17.4
11, 9.30 a. m			68	97.0	21.4	17.4
11, 11.30 a. m			71	99.1	21.4	17.0
11, 1.00 p. m		69.95				
11, 1.35 p. m			74	98.8	21.6	17.9
11, 3.10 p. m			70	99.0	21.7	18.0
11, 5.10 p. m			68	98.8	21.8	18.4
11, 7.00 p. m	66.86	71.11				
11, 7.15 p. m			85	99.7	21.6	18.5
11, 9.35 p. m			72	99.0	22.0	19.4
11, 10.00 p. m		70.75				
12, 1.00 a. m			65	97.4	21.7	18.6
12, 7.00 a. m	65.98	70.00				

TABLE 34.—*Weight, composition, and heats of combustion of foods—Metabolism experiment No. 7.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2795	Beef, fried	169.0	112.9	43.1	11.3	....	6.90	29.22	4.38	340
2796	Beef, dried	25.0	16.4	6.1	.7	....	.98	3.58	.54	40
2798	Eggs, boiled	141.0	112.7	14.1	12.8	....	2.25	15.45	2.50	201
2801	Butter	15.0	1.5	.2	12.9	....	.03	9.41	1.47	119
2800	Milk	575.0	500.2	20.1	27.6	22.4	3.22	38.87	5.69	427
2804	Bread, rye	150.0	63.6	12.6	.9	70.5	2.01	38.57	5.30	373
2786	Sugar	45.0	....	....	....	45.0	....	18.95	2.92	178
2797	Beans, baked	125.0	88.6	7.7	1.2	24.9	1.25	15.70	2.23	157
	Pears, canned	150.0	120.7	.5	.8	27.6	.06	11.00	1.77	115
	Total	....	1,016.6	104.4	68.2	190.4	16.70	180.75	26.80	1,950
	Alcohol	72.5	....	....	....	[1] 123.0	....	37.82	9.46	512
	Total	....	1,016.6	104.4	68.2	313.4	16.70	218.57	36.26	2,462

[1] One gram of alcohol calculated as isodynamically equivalent to 1.7 grams carbohydrates, this being the ratio of the heats of combustion (4.1 to 7.1).

TABLE 35.—*Weight, composition, and heats of combustion of fresh feces—Metabolism experiment No. 7.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2810	Feces, 4 days	198.0	140.60	22.4	9.7	15.1	3.58	26.59	3.51	303
	Average, 1 day	49.5	35.15	5.6	2.4	3.8	.90	6.65	.88	76

TABLE 36.—*Amounts and composition of urine—Metabolism experiment No. 7.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.		Carbon.	
1897.		*Grams.*		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*
June 8-9	7 a. m. to 1 p. m	473.3	1.025	1.37	6.48		
	1 p. m. to 7 p. m	318.7	1.026	1.34	4.27		
	7 p. m. to 1 a. m	480.0	1.017	1.14	5.47		
	1 a. m. to 7 a. m	185.4	1.025	1.79	3.32		
	Total	1,457.4			19.54		14.64
	Total by composite	1,457.4		1.34	19.53		
9-10	7 a. m. to 1 p. m	649.0	1.015	.79	5.13		
	1 p. m. to 7 p. m	732.0	1.016	.72	5.28		
	7 p. m. to 1 a. m	659.0	1.012	.72	4.74		
	1 a. m. to 7 a. m	162.8	1.024	1.62	2.64		
	Total	2,202.8			17.79		13.33
	Total by composite	2,202.8		.81	17.84		
10-11	7 a. m. to 1 p. m	437.1	1.016	.92	4.02		
	1 p. m. to 7 p. m	439.2	1.023	1.00	4.39		
	7 p. m. to 1 a. m	321.9	1.020	1.23	3.96		
	1 a. m. to 7 a. m	301.0	1.019	1.23	3.70		
	Total	1,499.2			16.07		12.04
	Total by composite	1,499.2		1.08	16.19		
11-12	7 a. m. to 1 p. m	273.5	1.024	1.37	3.75		
	1 p. m. to 7 p. m	392.0	1.022	1.25	4.90		
	7 p. m. to 1 a. m	531.0	1.017	1.05	5.58		
	1 a. m. to 7 a. m	181.5	1.024	1.68	3.05		
	Total	1,378.0			17.28		12.94
	Total by composite	1,378.0		1.26	17.37		
	Total for 4 days, by periods	6,537.4			70.68		
	Composite for 4 days	6,537.4		1.08	70.60	0.81	52.95
12-13	7 a. m. to 1 p. m	271.6	1.026	1.42	3.86		
	1 p. m. to 7 p. m	330.4	1.029	1.32	4.36		
	7 p. m. to 1 a. m	221.0	1.026	1.48	3.27		
	1 a. m. to 7 a. m	287.3	1.023	1.38	3.96		
	Total	1,110.3			15.45		11.82

TABLE 36.—*Amounts and composition of urine—Metabolism experiment No. 7*—Cont'd.

Date.	Period.	Hydrogen.		Water.		Heats of combustion.	
						Per gram.	Total.
		Per cent.	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
1897.							
June 8–9	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.97		1,382.0		
	Total by composite					0.103	150
9–10	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.62		2,134.2		
	Total by composite					.057	126
10–11	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.27		1,437.2		
	Total by composite					.090	135
11–12	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.52		1,311.4		
	Total by composite					.093	128
	Total for 4 days, by periods						538
	Composite for 4 days	0.22	14.38	95.83	6,264.8	.087	[1] 569
12–13	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.20		1,049.1	.115	128

[1] Total heat of combustion as determined in dried urine gives 562 calories (see p. 23).

TABLE 37.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 7.*

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (—) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (—) over preceding period.	Water. Change in weight of absorbers. Gain (+) or loss (—).	Water. Drip from absorbers.	Water. Total amount gained (+) or lost (—) during the period.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8-9	7 a. m	30.8	....	52.2	....	....	....	....
	1 p. m	44.9	+14.1	53.6	+ 1.4	+ 42	....	+ 43.4
	7 p. m	48.6	+ 3.7	59.8	+ 6.2	+ 48	50.8	+105.0
	1 a. m	46.7	— 1.9	60.9	+ 1.1	+ 14	12.7	+ 27.8
	7 a. m	30.0	—16.7	57.6	— 3.3	+ 14	12.8	+ 23.5
	Total	....	— .8	....	+ 5.4	+118	76.3	+199.7
9-10	1 p. m	43.4	+13.4	53.8	— 3.8	+ 17	21.3	+ 34.5
	7 p. m	57.8	+14.4	58.9	+ 5.1	+ 17	21.3	+ 43.4
	1 a. m	43.8	—14.0	64.7	+ 5.8	— 13	47.8	+ 40.6
	7 a. m	26.3	—17.5	53.6	—11.1	— 12	47.8	+ 24.7
	Total	....	— 3.7	....	— 4.0	+ 9	138.2	+143.2
10-11	1 p. m	59.3	+33.0	57.5	+ 3.9	+ 8	21.5	+ 33.4
	7 p. m	49.8	— 9.5	56.3	— 1.2	+ 32	48.3	+ 79.1
	1 a. m	35.1	—14.7	61.7	+ 5.4	— 12	46.3	+ 39.7
	7 a. m	26.2	— 8.9	50.7	—11.0	— 12	46.4	+ 23.4
	Total	....	— .1	....	— 2.9	+ 16	162.5	+175.6
11-12	1 p. m	41.6	+15.4	42.3	— 8.4	+ 6	34.9	+ 32.5
	7 p. m	48.2	+ 6.6	45.2	+ 2.9	+ 12	58.6	+ 73.5
	1 a. m	33.0	—15.2	46.5	+ 1.3	— 29	44.5	+ 16.8
	7 a. m	24.7	— 8.3	40.6	— 5.9	— 29	44.5	+ 9.6
	Total	....	— 1.5	....	—10.1	— 40	182.5	+132.4
	Total for 4 days	....	— 6.1	....	—11.6	+103	559.5	+650.9

TABLE 38.—*Record of carbon dioxid in ventilating air current—Metabolism experiment No. 7.*

Date.	Period.	(*a*) Volume of ventilating air current.	Carbon dioxid per liter. (*b*) In incoming air.	(*c*) In outgoing air.	(*d*) Excess in outgoing air ($c-b$).	(*e*) Total excess in outgoing air ($d \times a$).	(*f*) Correction for carbon dioxid in apparatus.	(*g*) Corrected weight carbon dioxid exhaled by subject ($e+f$).	(*h*) Total weight carbon exhaled in carbon dioxid ($g \times \frac{3}{11}$).
1897.		*Liters.*	*Mgs.*	*Mgs.*	*Mgs.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8-9	7 a. m. to 1 p. m	23,060	0.506	8.872	8.366	192.9	+14.1	207.0	56.5
	1 p. m. to 7 p. m	22,639	.510	9.355	8.845	200.2	+ 3.7	203.9	55.6
	7 p. m. to 1 a. m	24,249	.491	9.977	9.486	230.0	— 1.9	228.1	62.2
	1 a. m. to 7 a. m	24,530	.519	6.525	6.006	147.3	—16.7	130.6	35.6
	Total	94,478				770.4	— 0.8	769.6	209.9
9-10	7 a. m. to 1 p. m	22,951	.705	9.619	8.914	204.6	+13.4	218.0	59.4
	1 p. m. to 7 p. m	22,656	.503	10.011	9.508	215.4	+14.4	209.8	62.7
	7 p. m. to 1 a. m	24,094	.458	9.723	9.265	223.2	—14.0	209.2	57.0
	1 a. m. to 7 a. m	25,812	.458	6.479	6.021	155.4	—17.5	137.9	37.6
	Total	95,513				798.6	— 3.7	794.9	216.7
10-11	7 a. m. to 1 p. m	22,143	.828	9.358	8.530	188.9	+33.0	221.9	60.5
	1 p. m. to 7 p. m	23,301	.548	9.795	9.247	215.4	— 9.5	205.9	56.2
	7 p. m. to 1 a. m	26,107	.512	10.447	9.935	259.4	—14.7	244.7	66.7
	1 a. m. to 7 a. m	25,221	.535	5.927	5.392	136.0	— 8.9	127.1	34.7
	Total	96,772				799.7	— 0.1	799.6	218.1
11-12	7 a. m. to 1 p. m	23,347	.706	8.458	7.752	181.0	+15.4	196.4	53.6
	1 p. m. to 7 p. m	23,596	.931	9.769	8.838	208.5	+ 6.6	215.1	58.6
	7 p. m. to 1 a. m	27,640	.663	9.725	9.062	250.5	—15.2	235.3	64.2
	1 a. m. to 7 a. m	25,773	.697	6.270	5.573	143.6	— 8.3	135.3	36.9
	Total	100,356				783.6	— 1.5	782.1	213.3
	Total for 4 days	387,119				3,152.3	— 6.1	3,146.2	858.0

TABLE 39.—*Record of water in ventilating air current—Metabolism experiment No. 7.*

Date.	Period.	(a) Volume of ventilating air current.	Water per liter. (b) In incoming air.	(c) In outgoing air.	(d) Excess in outgoing air (c—b).	(e) Total excess in outgoing air (d×a).	(f) Condensed in freezers.	(g) Correction for water remaining in chamber.	(h) Total water exhaled (e+f+g).
1897.		*Liters.*	*Mgs.*	*Mgs.*	*Mgs.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8–9	7 a. m. to 1 p. m	23,060	1.103	1.432	0.329	7.6	220.9	43.4	271.9
	1 p. m. to 7 p. m	22,639	1.049	1.579	.530	12.0	216.0	105.0	333.0
	7 p. m. to 1 a. m	24,249	1.057	1.432	.375	9.1	265.0	27.8	301.9
	1 a. m. to 7 a. m	24,530	1.011	1.430	.419	10.3	255.6	23.5	289.4
	Total	94,478	......	......	......	39.0	957.5	199.7	1,196.2
9–10	7 a. m. to 1 p. m	22,951	1.018	1.394	.376	8.6	224.8	34.5	267.9
	1 p. m. to 7 p. m	22,656	1.142	1.486	.344	7.8	235.7	43.4	286.9
	7 p. m. to 1 a. m	24,094	1.000	1.553	.553	13.3	266.2	40.6	320.1
	1 a. m. to 7 a. m	25,812	1.039	1.545	.506	13.1	264.1	24.7	301.9
	Total	95,513	......	......	......	42.8	990.8	143.2	1,176.8
10–11	7 a. m. to 1 p. m	22,143	1.116	1.519	.403	8.9	218.2	33.4	260.5
	1 p. m. to 7 p. m	23,301	1.147	1.616	.469	10.9	225.9	79.1	315.9
	7 p. m. to 1 a. m	26,107	1.150	1.692	.542	14.2	292.1	39.7	346.0
	1 a. m. to 7 a. m	25,221	1.049	1.480	.431	10.9	250.2	23.4	284.5
	Total	96,772	......	......	......	44.9	986.4	175.6	1,206.9
11–12	7 a. m. to 1 p. m	23,347	1.202	1.419	.217	5.0	215.5	32.5	253.0
	1 p. m. to 7 p. m	23,596	.993	1.499	.506	11.9	235.0	73.5	320.4
	7 p. m. to 1 a. m	27,640	1.202	1.494	.292	8.1	304.6	16.8	329.5
	1 a. m. to 7 a. m	25,773	1.202	1.399	.197	5.1	251.6	9.6	266.3
	Total	100,356	......	......	......	30.1	1,006.7	132.4	1,169.2
	Total for 4 days.	387,119	......	......	......	156.8	3,941.4	650.9	4,749.1

TABLE 40.—*Summary of calorimetric measurements—Metabolism experiment No. 7.*

Date.	Period.	(*a*) Heat measured in terms of C t_1 to t_2.	(*b*) Average range in temperature between incoming and outgoing water, t_1 to t_2.	(*c*) Mean specific heat of water for range t_1 to t_2.	(*d*) Heat measured in terms of C_{20} ($a \times c$).	(*e*) Change of temperature of calorimeter.
1897.		*Calories.*	*Degrees.*		*Calories.*	*Degrees.*
June 8-9	7 a. m. to 1 p. m	517.2	6.12–14.82	1.0028	518.7	—0.03
	1 p. m. to 7 p. m	503.3	5.82–13.73	1.0031	504.9	+ .02
	7 p. m. to 1 a. m	480.0	7.38–15.17	1.0023	481.1	— .01
	1 a. m. to 7 a. m	291.3	10.62–16.76	1.0015	291.7	+ .10
	Total	1,791.8	....	....	1,796.4	....
9–10	7 a. m. to 1 p. m	509.7	5.96–14.18	1.0030	511.2	+ .07
	1 p. m. to 7 p. m	561.4	6.11–15.89	1.0026	562.9	— .13
	7 p. m. to 1 a. m	475.4	7.10–15.27	1.0025	476.6	— .05
	1 a. m. to 7 a. m	274.4	11.02–17.12	1.0014	274.8	+ .06
	Total	1,820.9	....	....	1,825.5	....
10–11	7 a. m. to 1 p. m	491.5	6.85–14.90	1.0025	492.7	....
	1 p. m. to 7 p. m	546.5	4.51–14.09	1.0033	548.3	— .08
	7 p. m. to 1 a. m	497.5	8.00–14.97	1.0023	498.7	+ .05
	1 a. m. to 7 a. m	288.3	10.94–16.32	1.0015	288.7	....
	Total	1,823.8	....	....	1,828.4	....
11-12	7 a. m. to 1 p. m	452.6	6.18–14.43	1.0029	453.9	+ .10
	1 p. m. to 7 p. m	530.0	5.98–14.83	1.0029	531.5	— .03
	7 p. m. to 1 a. m	463.8	8.54–15.35	1.0025	465.0	— .07
	1 a. m. to 7 a. m	280.0	11.82–16.62	1.0013	280.4	....
	Total	1,726.4	....	....	1,730.8	....
	Total for 4 days	....	....	....	7,181.1	....

TABLE 40.—*Summary of calorimetric measurements—Metabolism experiment No. 7*—Continued.

Date.	Period.	(*f*) Capacity correction of calorimeter ($e \times 60$).	(*g*) Capacity correction due to temperature of food and dishes.	(*h*) Water vaporized, equals total amount exhaled less amount condensed in chamber.	(*i*) Heat used in vaporization of water ($h \times .592$).	(*k*) Total heat determined ($d+f+g+i$).
1897.		*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
June 8–9	7 a. m. to 1 p. m	− 2	− 6.1	229.9	136.1	646.7
	1 p. m. to 7 p. m	+ 1	− 4.4	234.2	138.7	640.2
	7 p. m. to 1 a. m	+ 6	+ 4.3	275.2	162.9	654.3
	1 a. m. to 7 a. m	....	....	262.6	155.5	447.2
	Total	+ 5	− 6.2	1,001.9	593.2	2,388.4
9–10	7 a. m. to 1 p. m	+ 4	− 1.6	229.6	135.9	649.5
	1 p. m. to 7 p. m	− 8	− 4.7	248.6	147.2	697.4
	7 p. m. to 1 a. m	− 3	− 1.2	285.3	168.9	641.3
	1 a. m. to 7 a. m	+ 4	....	266.1	157.5	436.3
	Total	− 3	− 7.5	1,029.6	609.5	2,424.5
10–11	7 a. m. to 1 p. m	....	− 5.2	231.0	136.8	624.3
	1 p. m. to 7 p. m	− 5	− 0.4	235.6	139.4	682.3
	7 p. m. to 1 a. m	+ 3	+ 1.8	311.7	184.5	688.0
	1 a. m. to 7 a. m	....	....	250.1	148.1	436.8
	Total	− 2	− 3.8	1,028.4	608.8	2,431.4
11–12	7 a. m. to 1 p. m	....	− 5.4	212.1	125.6	574.1
	1 p. m. to 7 p. m	+ 6	− 2.9	249.8	147.8	682.4
	7 p. m. to 1 a. m	− 2	+ 1.5	314.0	185.9	650.4
	1 a. m. to 7 a. m	− 4	....	250.8	148.5	424.9
	Total	....	− 6.8	1,026.7	607.8	2,331.8
	Total for 4 days	....	−24.3	4,086.6	2,419.3	9,576.1

TABLE 41.—*Alcohol excreted by the kidneys and by the skin and lungs—Metabolism experiment No. 7.*

Date.	Period.	Alcohol— Found in urine.	Found in respiratory products. In freezers.	In drip.	In air current.	Total excreted.	Total income.	Used in body.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 5	7 a. m. to 7 a. m.	0.93						
6	do	.91						
7	do	1.12						
8	do	.13	1.31 (June 8 and 9)	.08 (June 8–11)	2.00	2.81	72.54	69.73
9	do	.28			2.00	2.95	72.54	69.59
10	do	.38	.70		[1] 2.62	3.72	72.54	68.82
11	do	.08	.29		2.03	2.42	72.54	70.14
12	do	.02						
13	do	Trace.						
	Total for June 8, 9, 10, and 11	.87	2.30	.08	8.65	11.90	290.16	278.28

[1] By an accident some of the coffee and alcohol, sufficient to contain 2.18 grams absolute alcohol, was spilled upon the floor of the chamber and an equivalent amount was passed in for consumption by the subject. The actual amount of alcohol found in the air current during the day was 4.80 grams, of which it is assumed that 2.18 grams came from the alcohol spilled and the remainder (2.62 grams) from alcohol eliminated from the lungs and skin.

The figures in Table 41 demand a word of comment. The alcohol in the respiratory products, i. e., that excreted by the lungs and skin, was found mostly in the air current after it had passed the freezer. But little was retained with the ice in the freezer and still less was collected in the drip water. The determinations of this elimination of alcohol were made according to the first of the methods described above, pp. 26–29, and they doubtless give too high results, but are of value as indicating that the amount of excretion is relatively small. The total amount as thus measured for the four days was only 12 grams as compared with 290 grams consumed in the food, or about 4 per cent. Later experiments (see pp. 27, 109) lead us to doubt whether the actual amount of alcohol eliminated from the body could have been much more than half that found by the method in this experiment.

It should be added that quantitative tests gave no evidence of the presence of aldehyde or other products of the partial oxidation of alcohol in either urine or air current.

The computed data of income and outgo are as follows:

TABLE 42.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 7.*

Date.	Nitrogen.				Carbon.					
	(*a*) In food.	(*b*) In feces.	(*c*) In urine.[1]	(*d*) Gain(+) or loss(—) $a-(b+c)$.	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain(+) or loss(—) $e-(f+g+h+i)$.
1897.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8–9, 7 a. m. to 7 a. m	16.7	0.9	19.6	—3.8	218.6	6.6	14.7	209.9	1.5	—14.1
June 9–10, 7 a. m. to 7 a. m	16.7	.9	17.8	—2.0	218.6	6.7	13.3	216.7	1.5	—19.6
June 10–11, 7 a. m. to 7 a. m	16.7	.9	16.2	—.4	218.6	6.6	12.0	218.1	1.9	—20.0
June 11–12, 7 a. m. to 7 a. m	16.7	.9	17.3	—1.5	218.6	6.7	13.0	213.3	1.3	—15.7
Total, 4 days	66.8	3.6	70.9	—7.7	874.4	26.6	53.0	858.0	6.2	—69.4
Average, 1 day	16.7	.9	17.7	—1.9	218.6	6.7	13.3	214.5	1.6	—17.4

[1] Including nitrogen in perspiration. The underclothes of the subject at the end of experiment were extracted with distilled water and the nitrogen determined, which amounted to 0.19 gram N. (See p. 24.)

The amount of water in the mixture of coffee infusion and alcohol and the amount of drinking water actually consumed each day during this experiment are shown in the following table. The alcohol mixture was made by adding to 875 grams of coffee infusion 45 grams of sugar and 80 grams of 90.67 per cent alcohol, thus making a total of 1,000 grams, containing 882.5 grams water.

Record of drinking water and coffee—Metabolism experiment No. 7.

Date.	Coffee infusion.	Drinking water.	Total drink.
	Grams.	*Grams.*	*Grams.*
June 8	882.5	300.0	1,182.5
9	882.5	500.0	1,382.5
10	882.5	526.5	1,409.0
11	882.5	500.0	1,382.5
Total	3,530.0	1,826.5	5,356.5

To avoid loss of sugar and alcohol the coffee was carefully drained out of the vessel in which it was passed into the chamber, so that the whole 882.5 grams of water were drunk each day. The amount of

drinking water served the first day proved to be insufficient for the satisfying of the subject's thirst, so larger amounts were served on the following days.

TABLE 43.—*Income and outgo of water and hydrogen—Metabolism experiment No. 7.*

Date.	Period.	Water. (a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.[1]	(f) Apparent loss $a+b-(c+d+e)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8- 9	7 a. m. to 7 a. m..	1,016.6	1,182.5	35.1	1,382.0	1,201.2	— 419.2
9-10	.....do...........	1,016.6	1,382.5	35.2	2,134.2	1,182.8	— 953.1
10-11	.....do...........	1,016.6	[2]1,409.0	35.1	1,437.2	1,211.9	— 258.6
11-12	.....do...........	1,016.6	1,382.5	35.2	1,311.4	1,176.2	— 123.7
	Total, 4 days...	4,066.4	5,356.5	140.6	6,264.8	4,772.1	—1,754.6
	Average, 1 day.	1,016.6	1,339.1	35.2	1,566.2	1,193.0	— 438.7

Date.	Period.	Hydrogen. (g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain $g-(h+i+k)$.	(m) Loss from water. $(f \div 9)$.	(n) Total gain (+) or loss (—) $(l+n)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8- 9	7 a. m. to 7 a. m..	36.3	0.9	4.0	0.4	+ 31.0	46.6	—15.6
9-10	.....do..........	36.3	.9	3.6	.4	+ 31.4	105.9	—74.5
10-11	.....do..........	36.3	.9	3.3	.5	+ 31.6	28.7	+ 2.9
11-12	.....do..........	36.3	.9	3.5	.3	+ 31.6	13.7	+17.9
	Total, 4 days...	145.2	3.6	14.4	1.6	+125.6	194.9	—69.3
	Average, 1 day.	36.3	.9	3.6	.4	+ 31.4	48.7	—17.3

[1] Including 23 grams of water in perspiration.
[2] Including 26.5 grams water in coffee spilled in chamber.

TABLE 41.—*Gain or loss of protein (N × 6.25), fat, and water—Metabolism experiment No. 7.*

Date.	Period.	(a) Nitrogen gained (+) or lost (—).	(b) Protein gained (+) or lost (—) (a × 6.25).	(c) Total carbon gained (+) or lost (—).	(d) Carbon in protein gained (+) or lost (—) (b × .53).	(e) Carbon in fat, etc., gained (+) or lost (—) (c—d).	(f) Fat gained (+) or lost (—) (e ÷ .765).
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8- 9	7 a. m. to 7 a. m	—3.8	—23.8	—14.1	—12.6	— 1.5	— 2.0
9-10	.....do	—2.0	—12.5	—19.6	— 6.7	—12.9	—16.9
10-11	.....do	— .4	— 2.5	—20.0	— 1.3	—18.7	—24.4
11-12	.....do	—1.5	— 9.4	—15.7	— 5.0	—10.7	—14.0
	Total, 4 days	—7.7	—48.2	—69.4	—25.6	—43.8	—57.3
	Average, 1 day	—1.9	— 12.0	—17.4	— 6.4	—11.0	—14.3

Date.	Period.	(g) Total hydrogen gained (+) or lost (—).	(h) Hydrogen in protein gained (+) or lost (—) (b × .07).	(i) Hydrogen in fat gained (+) or lost (—) (f × .12).	(k) Hydrogen in water, etc., gained (+) or lost (—) g—(h+i).	(l) Water gained (+) or lost (—) (k × 9).
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
June 8- 9	7 a. m. to 7 a. m	—15.6	—1.7	— .2	—13.7	—123.3
9-10	.....do	—74.5	— .9	—2.0	—71.6	—644.4
10-11	.....do	+ 2.9	— .2	—3.0	+ 6.1	+ 54.9
11-12	.....do	+17.9	— .6	—1.7	+20.2	+181.8
	Total, 4 days	—69.3	—3.4	—6.9	—59.0	—531.0
	Average, 1 day	—17.3	— .8	—1.7	—14.8	—132.8

TABLE 45.—*Income and outgo of energy—Metabolism experiment No. 7.*

Date.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(m) Heat of combustion of alcohol eliminated.	(d) Estimated heat of combustion of protein gained (+) or lost (—).	(e) Estimated heat of combustion of fat gained (+) or lost (—).	(f) Estimated energy of material oxidized in the body $a—(b+c+m+d+e)$.	(g) Heat determined.	(h) Heat determined greater (+) or less (—) than estimated $(f—g)$.	(i) Heat determined greater (+) or less (—) than estimated $(h \div f)$.
1897.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
June 8–9, 7 a. m. to 7 a. m.	2,462	76	150	20	—137	— 19	2,372	2,388	+ 16	+0.7
June 9–10, 7 a. m. to 7 a. m.	2,462	76	126	21	— 72	—159	2,470	2,425	— 45	—1.8
June 10–11, 7 a. m. to 7 a. m.	2,462	76	134	26	— 14	—229	2,469	2,431	— 38	—1.5
June 11–12, 7 a. m. to 7 a. m.	2,642	76	128	17	— 54	—132	2,427	2,332	— 95	—3.9
Total, 4 days	9,848	304	538	84	—277	—539	9,738	9,576	—162	....
Average, 1 day	2,462	76	135	21	— 69	—135	2,434	2,394	— 40	—1.6

In this experiment the average daily income of energy, i. e., the estimated heat of combustion of material actually oxidized in the body, averaged 2,434 calories per day; and the outgo, i. e., the heat given off from the body and measured, was 2,394 calories. The measured outgo was thus 98.4 per cent of the theoretical income. This discrepancy of 1.6 per cent was smaller than that of either of the two preceding or the next succeeding experiments.

DETAILS OF METABOLISM EXPERIMENT NO. 8.

The subject entered the chamber of the calorimeter on the evening of November 7, 1897, and the experiment proper commenced as usual at 7 a. m. the following morning. The experiment was a so-called rest experiment—that is, the subject engaged in no muscular work other than that required in the regular routine of observations outlined in the daily programme. The diet contained no alcohol, but water was supplied at regular intervals during the day, so that the total amount of drink was about the same as that in No. 7, when alcohol was taken in successive portions. The amount of water vapor in the chamber was not sufficient to cause an appreciable amount of drip. The explanation of the small amount of drip here as compared with the larger amount in experiment No. 7, also a rest experiment, is doubtless to be found in the higher temperature of the water as it entered the absorbers in this experiment. As in previous experiments, the furniture and bedding were weighed at the beginning and end of the experiment, but no appreciable change in

weight was found. The methods of calculation of the tables in this experiment are the same as previously described. The results are recorded in Tables 46–59, which follow.

TABLE 46.—*Daily menu—Metabolism experiment No. 8.*

Menu.	Grams.	Menu.	Grams.
BREAKFAST.		DINNER—continued.	
Boiled eggs	95	Milk	100
Rye bread	100	Sugar	10
Butter	15	Coffee	300
Milk	250	SUPPER.	
Sugar	15	Rye bread	125
Coffee	300	Milk	500
DINNER.		Sugar	15
Beef, fried	150	Butter	10
Baked beans	125	Apples	200
Rye bread	100	Coffee	300
Butter	10		

TABLE 47.—*Daily programme—Metabolism experiment No. 8.*

7.00 a. m	Rise; pass urine; weigh self stripped; collect drip; weigh absorbers.	3.30 p. m	Drink 200 grams water.
7.45 a. m	Breakfast.	6.30 p. m	Supper.
10.30 a. m	Drink 200 grams of water.	7.00 p. m	Pass urine; collect drip; weigh absorbers.
1.00 p. m	Pass urine; collect drip; weigh absorbers.	10.00 p. m	Pass urine; drink 200 grams water; weigh self stripped; retire.
1.30 p. m	Dinner.	1.00 a. m	Pass urine.

TABLE 48.—*Summary of diary—Metabolism experiment No. 8.*

Time.	Weight of subject.		Pulse rate per minute.	Temperature.	Hygrometer.	
	Without clothes.	With clothes.			Dry bulb.	Wet bulb.
1897.	*Kilograms.*	*Kilograms.*		°*F.*	°*C.*	°*C.*
Nov. 8, 7.00 a. m	67.65	71.55	...	...	22.4	18.2
8, 9.00 a. m	...	...	73	98.7	...	...
8, 11.00 a. m	...	...	...	...	21.7	17.0
8, 2.30 p. m	...	...	...	99.0	22.4	18.6
8, 5.00 p. m	...	...	...	...	21.3	17.4
8, 9.45 p. m	...	...	68	98.6	22.4	18.4
8, 10.00 p. m	67.74	...	...	...	...	...
9, 7.00 a. m	66.52	...	...	...	22.2	17.9
9, 8.15 a. m	...	...	62	98.1	...	...
9, 11.30 a. m	...	...	...	...	21.7	17.2
9, 4.30 p. m	...	...	...	98.3	21.0	16.8
9, 10.00 p. m	67.26	...	66	98.6	22.1	18.0
10, 7.00 a. m	66.26	...	...	...	...	...
10, 7.30 a. m	...	...	63	97.4	21.4	17.1
10, 11.30 a. m	...	...	...	...	21.0	16.4

TABLE 48.—*Summary of diary—Metabolism experiment No. 8*—Continued.

Time.	Weight of subject.		Pulse rate per minute.	Temperature.	Hygrometer.	
	Without clothes.	With clothes.			Dry bulb.	Wet bulb.
1897.	*Kilograms.*	*Kilograms.*		*°F.*	*°C.*	*°C.*
Nov. 10, 3.30 p. m				98.4	22.1	17.2
10, 7.15 p. m					22.5	19.3
10, 10.00 p. m	67.22					
10, 10.15 p. m			64	98.6	22.0	18.4
11, 7.00 a. m	66.20					
11, 7.30 a. m			64	97.0	21.0	17.2
11, 10.30 a. m					21.2	17.0
11, 1.15 p. m					21.4	16.9
11, 7.15 p. m					22.5	18.4
11, 10.00 p. m	67.49					
11, 10.20 p. m			66	98.2	22.0	18.4
12, 7.00 a. m	66.48	70.37	58	96.9	21.8	17.6

TABLE 49.—*Weight, composition, and heats of combustion of foods—Metabolism experiment No. 8.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2821	Beef, fried	150	89.7	47.4	10.6		7.59	32.43	4.67	362
2819	Eggs	95	70.6	11.8	10.3		1.88	14.51	2.18	170
2827	Butter	35	3.5	.5	29.8		.09	22.28	3.54	272
2826	Milk	850	722.5	28.9	43.3	49.3	4.67	67.06	9.77	767
2815	Bread, rye	325	120.6	32.2	.3	166.4	5.13	89.86	13.00	893
———	Sugar	40				40.0		16.84	2.59	159
2817	Beans, baked	125	89.9	8.2	.4	23.7	1.31	14.90	2.12	151
2823	Apples	200	169.6	.4	1.0	28.4	.08	12.80	1.34	123
	Total		1,266.4	129.4	95.7	307.8	20.75	270.68	39.21	2,897

TABLE 50.—*Weight, composition, and heats of combustion of fresh feces—Metabolism experiment No. 8.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2825	Total for 4 days	284	198.0	31.5	16.8	21.9	5.03	42.32	5.79	467
	Avg. for 1 day	71	49.5	7.9	4.2	5.5	1.26	10.58	1.45	117

TABLE 51.—*Amounts and composition of urine—Metabolism experiment No. 8.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.		Carbon.	
1897.		*Grams.*		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*
Nov. 8–9	7 a. m. to 1 p. m	808.2	1.012	0.69	5.58	....	....
	1 p. m. to 7 p. m	841.6	1.012	.68	5.72	....	....
	7 p. m. to 1 a. m	1,348.6	1.006	.49	6.61	....	....
	1 a. m. to 7 a. m	209.2	1.019	1.44	3.01	....	....
	Total	3,207.6	....	....	20.92	....	14.92
	Total by composite	3,207.6	....	.65	20.85	....	....
9–10	7 a. m. to 1 p. m	466.6	1.016	.87	4.06	....	....
	1 p. m. to 7 p. m	362.0	1.024	1.32	4.78	....	....
	7 p. m. to 1 a. m	1,256.3	1.006	.57	7.16	....	....
	1 a. m. to 7 a. m	182.8	1.020	1.56	2.85	....	....
	Total	2,267.7	....	....	18.85	....	13.44
	Total by composite	2,267.7	....	.81	18.37	....	....
10–11	7 a. m. to 1 p. m	292.6	1.021	1.24	3.62	....	....
	1 p. m. to 7 p. m	434.1	1.023	1.28	5.56	....	....
	7 p. m. to 1 a. m	1,036.4	1.008	.65	6.74	....	....
	1 a. m. to 7 a. m	195.0	1.019	1.58	3.08	....	....
	Total	1,958.1	....	....	19.00	....	13.55
	Total by composite	1,958.1	....	.97	18.95	....	....
11–12	7 a. m. to 1 p. m	391.9	1.015	1.09	4.27	....	....
	1 p. m. to 7 p. m	392.4	1.022	1.36	5.33	....	....
	7 p. m. to 1 a. m	853.6	1.008	.74	6.31	....	....
	1 a. m. to 7 a. m	201.2	1.018	1.66	3.34	....	....
	Total	1,839.1	....	....	19.25	....	13.73
	Total by composite	1,839.1	....	1.06	19.44	....	....
	Total 4 days, by periods	9,272.5	....	....	78.02	....	....
	Composite 4 days	9,272.5	....	.84	77.90	0.60	55.64
12–13	7 a. m. to 1 p. m	202.2	1.025	1.68	3.40	....	....
	1 p. m. to 7 p. m	357.0	1.025	1.22	4.35	....	....
	7 p. m. to 1 a. m	394.3	1.022	1.25	4.93	....	....
	1 a. m. to 7 a. m	321.6	1.022	1.22	3.92	....	....
	Total	1,275.1	....	1.30	16.60	....	11.85
13	7 a. m. to 1 p. m	396.5	....	1.09	4.32	....	....

TABLE 51.—*Amounts and composition of urine—Metabolism experiment No. 8*—Cont'd.

Date.	Period.	Hydrogen.		Water.		Heats of combustion.	
						Per gram.	Total.
1897.		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
Nov. 8-9	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		4.22		3,120.1		
	Total by composite					0.049	157
9-10	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.81		2,188.8		
	Total by composite					.067	152
10-11	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.84		1,878.6		
	Total by composite					.072	141
11-12	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.89		1,758.6		
	Total by composite					.087	160
	Total 4 days, by periods						610
	Composite 4 days	0.17	15.76	96.48	8,946.1	.071	658
12-13	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		2.14		1,237.3	.127	162
13	7 a. m. to 1 p. m						

TABLE 52.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 8.*

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (—) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (—) over preceding period.	Water. Change in weight of absorbers. Gain (+) or loss (—).	Water. Drip from absorbers.	Water. Total amount gained (+) or lost (—) during the period.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m	34.6	....	71.8	....	....	....	....
	1 p. m	49.9	+15.3	55.6	—16.2	+35	....	+ 18.8
	7 p. m	47.1	— 2.8	50.3	— 5.3	+68	38.6	+101.3
	1 a. m	32.5	—14.6	58.7	+ 8.4	— 3	17.5	+ 22.9
	7 a. m	32.7	+ .2	64.2	+ 5.5	— 3	17.5	+ 20.0
	Total	....	— 1.9	....	— 7.6	+97	73.6	+163.0
9-10	1 p. m	53.2	+20.5	53.4	—10.8	+16	....	+ 5.2
	7 p. m	58.2	+ 5.0	53.6	+ .2	+36	....	+ 36.2
	1 a. m	30.0	—28.2	53.1	— .5	—23	28.2	+ 4.7
	7 a. m	29.8	— .2	54.4	+ 1.3	—21	28.1	+ 5.4
	Total	....	— 2.9	....	— 9.8	+ 5	56.3	+ 51.5
10-11	1 p. m	49.7	+19.9	49.6	— 4.8	+ 1	....	— 3.8
	7 p. m	68.6	+18.9	58.6	+ 9.0	+ 6	32.3	+ 47.3
	1 a. m	27.9	—40.7	55.1	— 3.5	—11	29.2	+ 14.7
	7 a. m	27.6	— .3	48.9	— 6.2	—11	29.2	+ 12.0
	Total	....	— 2.2	....	— 5.5	—15	90.7	+ 70.2
11-12	1 p. m	38.9	+11.3	44.9	— 4.0	+ 6	16.4	+ 18.4
	7 p. m	61.3	+22.4	52.9	+ 8.0	+20	16.5	+ 44.5
	1 a. m	31.0	—30.3	55.8	+ 2.9	—22	16.5	— 2.6
	7 p. m	29.1	— 1.9	50.2	— 5.6	—22	16.5	— 11.1
	Total	....	+ 1.5	....	+ 1.3	—18	65.9	+ 48.2
	Total for 4 days	....	— 5.5	....	—21.6	+69	286.5	+332.9

TABLE 53.—*Record of carbon dioxid in ventilating air current—Metabolism experiment No. 8.*

Date.	Period.	(*a*) Volume of ventilating air-current.	Carbon dioxid per liter. (*b*) In incoming air.	(*c*) In outgoing air.	(*d*) Excess in outgoing air ($c-b$).	(*e*) Total excess in outgoing air ($d \times a$).	(*f*) Correction for carbon dioxid in apparatus.	(*g*) Corrected weight carbon dioxid exhaled by subject ($e+f$).	(*h*) Total weight carbon exhaled in carbon dioxid ($g \times \frac{3}{11}$).
1897.		*Liters.*	*Mg.*	*Mgs.*	*Mgs.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m. to 1 p. m	23, 923	0. 706	9. 602	8. 896	212. 8	+15. 3	228. 1	62. 2
	1 p. m. to 7 p. m	23, 736	. 655	11. 574	10. 919	259. 2	— 2. 8	256. 4	69. 9
	7 p. m. to 1 a. m	26, 939	. 603	9. 356	8. 753	235. 8	—14. 6	221. 2	60. 3
	1 a. m. to 7 a. m	25, 307	. 501	5. 656	5. 155	130. 5	+ . 2	130. 7	35. 6
	Total	99, 905	....	....	....	838. 3	— 1. 9	836. 4	228. 0
9-10	7 a. m. to 1 p. m	24, 219	. 584	9. 140	8. 556	207. 2	+20. 5	227. 7	62. 1
	1 p. m. to 7 p. m	24, 281	. 594	9. 653	9. 059	220. 0	+ 5. 0	225. 0	61. 4
	7 p. m. to 1 a. m	27, 724	. 607	10. 010	9. 403	260. 7	—28. 2	232. 5	63. 4
	1 a. m. to 7 a. m	27, 413	. 607	5. 905	5. 298	145. 2	— . 2	145. 0	39. 5
	Total	103, 637	....	....	....	833. 1	— 2. 9	830. 2	226. 4
10-11	7 a. m. to 1 p. m	24, 537	. 564	8. 696	8. 132	199. 5	+19. 9	219. 4	59. 8
	1 p. m. to 7 p. m	24, 094	. 564	9. 492	8. 928	215. 0	+18. 9	233. 9	63. 8
	7 p. m. to 1 a. m	27, 382	. 570	10. 518	9. 948	272. 4	—40. 7	231. 7	63. 2
	1 a. m. to 7 a. m	27, 149	. 633	5. 643	5. 010	136. 0	— . 3	135. 7	37. 0
	Total	103, 162	....	....	....	822. 9	— 2. 2	820. 7	223. 8
11-12	7 a. m. to 1 p. m	26, 248	. 650	8. 606	7. 956	208. 8	+11. 3	220. 1	60. 0
	1 p. m. to 7 p. m	25, 659	. 561	9. 302	8. 741	206. 8	+22. 4	229. 2	62. 5
	7 p. m. to 1 a. m	26, 341	. 563	9. 892	9. 329	245. 7	—30. 3	215. 4	58. 7
	1 a. m. to 7 a. m	26, 784	. 683	6. 056	5. 373	143. 9	— 1. 9	142. 0	38. 7
	Total	103, 032	....	....	....	805. 2	+ 1. 5	806. 7	219. 9
	Total for 4 days.	409, 736	....	....	....	3, 299. 5	— 5. 5	3, 294. 0	898. 1

TABLE 54.—*Record of water in ventilating air current—Metabolism experiment No. 8.*

Date.	Period.	(a) Volume of ventilating air current.	Water per liter. (b) In incoming air.	(c) In outgoing air.	(d) Excess in outgoing air (c—b).	(e) Total excess in outgoing air (d×a).	(f) Condensed in freezers.	(g) Correction for water remaining in chamber.	(h) Total water exhaled (e+f+g).
1897.		*Liters.*	*Mg.*	*Mgs.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m. to 1 p. m	23, 923	0. 973	1. 254	0. 281	6. 7	215. 0	18. 8	240. 5
	1 p. m. to 7 p. m	23, 736	. 960	1. 186	. 226	5. 4	197. 5	101. 3	304. 2
	7 p. m. to 1 a. m	26, 939	. 865	1. 122	. 257	6. 9	280. 1	22. 9	309. 9
	1 a. m. to 7 a. m	25, 307	. 699	. 972	. 273	6. 9	254. 8	20. 0	281. 7
	Total	99, 905				25. 9	947. 4	163. 0	1, 136. 3
9-10	7 a. m. to 1 p. m	24, 219	. 898	1. 256	. 358	8. 7	214. 2	5. 2	228. 1
	1 p. m. to 7 p. m	24, 281	. 886	1. 038	. 152	3. 7	214. 5	36. 2	254. 4
	7 p. m. to 1 a. m	27, 724	. 778	1. 081	. 303	8. 4	283. 0	4. 7	296. 1
	1 a. m. to 7 a. m	27, 413	. 712	. 932	. 220	6. 0	273. 0	5. 4	284. 4
	Total	103, 637				26. 8	984. 7	51. 5	1, 063. 0
10-11	7 a. m. to 1 p. m	24, 537	. 795	1. 004	. 209	5. 1	208. 8	— 3. 8	210. 1
	1 p. m. to 7 p. m	24, 094	. 766	. 926	. 160	3. 8	212. 2	47. 3	263. 3
	7 p. m. to 1 a. m	27, 382	. 675	. 941	. 266	7. 3	284. 6	14. 7	306. 6
	1 a. m. to 7 a. m	27, 149	. 632	. 866	. 234	6. 4	252. 7	12. 0	271. 1
	Total	103, 162				22. 6	958. 3	70. 2	1, 051. 1
11-12	7 a. m. to 1 p. m	26, 248	. 749	1. 014	. 265	7. 0	229. 5	18. 4	254. 9
	1 p. m. to 7 p. m	23, 659	. 872	1. 098	. 226	5. 3	216. 2	44. 5	266. 0
	7 p. m. to 1 a. m	26, 341	. 799	1. 076	. 277	7. 3	270. 6	— 2. 6	275. 3
	1 a. m. to 7 a. m	26, 784	. 714	. 906	. 192	5. 1	263. 1	—11. 1	257. 1
	Total	103, 032				24. 7	979. 4	49. 2	1, 053. 3
	Total for 4 days	409, 736				100. 0	3, 869. 8	333. 9	4, 303. 7

TABLE 55.—*Summary of calorimetric measurements—Metabolism experiment No. 8.*

Date.	Period.	(a) Heat measured in terms of C_{t_1} to t_2.	(b) Average range in temperature between incoming and outgoing water t_1 to t_2.	(c) Mean specific heat of water for range t_1 to t_2.	(d) Heat measured in terms of $C_{20}(a \times c)$.	(e) Change of temperature of calorimeter.
1897.		*Calories.*	*Degrees.*		*Calories.*	*Degrees.*
Nov. 8–9	7 a. m. to 1 p. m	537.8	6.63–11.78	1.0033	539.6	+0.20
	1 p. m. to 7 p. m	551.2	7.03–12.58	1.0031	552.9	....
	7 p. m. to 1 a. m	487.8	7.29–14.53	1.0026	489.1	— .55
	1 a. m. to 7 a. m	219.3	12.69–17.05	1.0011	219.5	+ .35
	Total	1,796.1	....	....	1,801.1	....
9–10	7 a. m. to 1 p. m	516.6	7.00–12.59	1.0031	518.2	+ .10
	1 p. m. to 7 p. m	528.9	5.71–12.43	1.0033	530.6	— .10
	7 p. m. to 1 a. m	457.0	9.99–14.93	1.0019	457.9	+ .01
	1 a. m. to 7 a. m	239.5	13.09–17.18	1.0010	239.7	— .10
	Total	1,742.0	....	....	1,746.4	....
10–11	7 a. m. to 1 p. m	509.2	5.67–12.08	1.0035	511.0	....
	1 p. m. to 7 p. m	481.9	7.52–13.68	1.0027	483.2	+ .40
	7 p. m. to 1 a. m	503.9	7.68–14.25	1.0025	505.2	— .48
	1 a. m. to 7 a. m	246.6	12.02–16.42	1.0013	246.9	+ .10
	Total	1,741.6	....	....	1,746.3	....
11–12	7 a. m. to 1 p. m	444.7	7.73–14.19	1.0025	445.8	+ .05
	1 p. m. to 7 p. m	527.8	6.91–14.14	1.0028	529.3	— .05
	7 p. m. to 1 a. m	457.9	7.92–14.68	1.0024	459.0	....
	1 a. m. to 7 a. m	251.5	12.37–16.96	1.0011	251.8	+ .05
	Total	1,681.9	....	....	1,685.9	....
	Total, 4 days	6,961.6	....	....	6,979.7	....

TABLE 55.—*Summary of calorimetric measurements—Metabolism experiment No. 8*—Continued.

Date.	Period.	(*f*) Capacity correction of calorimeter ($e\times60$).	(*g*) Correction due to temperature of food and dishes.	(*h*) Water vaporized equals total amount exhaled less amount condensed in chamber.	(*i*) Heat used in vaporization of water ($h\times.592$).	(*k*) Total heat determined ($d+f+g+i$).
1897.		*Calories.*	*Calories*	*Grams.*	*Calories.*	*Calories.*
Nov. 8–9	7 a. m. to 1 p. m	+12.0	— 14.3	205.5	121.7	659.0
	1 p. m. to 7 p. m	....	— 28.1	197.6	117.0	641.8
	7 p. m. to 1 a. m	—33.0	....	295.4	174.9	631.0
	1 a. m. to 7 a. m	+21.0	....	267.2	158.1	398.6
	Total	....	— 42.4	965.7	571.7	2,330.4
9–10	7 a. m. to 1 p. m	+ 6.0	— 13.6	212.1	125.6	636.2
	1 p. m. to 7 p. m	— 6.0	— 36.3	218.4	129.3	617.6
	7 p. m. to 1 a. m	+ .6	....	290.9	172.2	630.7
	1 a. m. to 7 a. m	— 6.0	....	280.3	165.9	399.6
	Total	— 5.4	— 49.9	1,001.7	593.0	2,284.1
10–11	7 a. m. to 1 p. m	....	— 20.4	209.1	123.8	614.4
	1 p. m. to 7 p. m	+24.0	— 12.9	225.0	133.2	627.5
	7 p. m. to 1 a. m	—28.8	....	288.4	170.7	647.1
	1 a. m. to 7 a. m	+ 6.0	....	252.9	149.7	402.6
	Total	+ 1.2	— 33.3	975.4	577.4	2,291.6
11–12	7 a. m. to 1 p. m	+ 3.0	— 19.7	232.5	137.6	566.7
	1 p. m. to 7 p. m	— 3.0	— 24.6	229.5	135.9	637.6
	7 p. m. to 1 a. m	....	....	280.8	166.2	625.2
	1 a. m. to 7 a. m	+ 3.0	....	262.6	155.5	410.3
	Total	+ 3.0	— 44.3	1,005.4	595.2	2,239.8
	Total, 4 days	— 1.2	—169.9	3,948.2	2,337.3	9,145.9

TABLE 56.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 8.*

Date.	Period.	Nitrogen. (*a*) In food.	Nitrogen. (*b*) In feces.	Nitrogen. (*c*) In urine.	Nitrogen. (*d*) Gain (+) or loss (—) $a-(b+c)$.	Carbon. (*e*) In food.	Carbon. (*f*) In feces.	Carbon. (*g*) In urine.	Carbon. (*h*) In respiratory products.	Carbon. (*k*) Gain (+) or loss (—) $e-(f+g+h)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8–9	7 a. m. to 7 a. m.	20.8	1.3	20.9	—1.4	270.7	10.6	14.9	228.0	+17.2
9–10	.....do	20.7	1.2	18.9	+ .6	270.7	10.6	13.4	226.4	+20.3
10–11	.....do	20.8	1.3	19.0	+ .5	270.7	10.6	13.6	223.8	+22.7
11–12	.....do	20.7	1.2	19.2	+ .3	270.7	10.6	13.7	219.9	+26.5
	Total, 4 days	83.0	5.0	78.0	.0	1082.8	42.4	55.6	898.1	+86.7
	Average, 1 day	20.8	1.3	19.5	.0	270.7	10.6	13.9	224.5	+21.7

The record of the water consumed each day during this experiment is shown in the following table. The water supplied in the coffee infusion was 900 grams per day, but on some days it was not completely drunk, as the figures show.

Record of drinking water and coffee—Metabolism experiment No. 8.

Date.	Coffee infusion.	Drinking water.	Total drink.
	Grams.	*Grams.*	*Grams.*
Nov. 8	882.4	596.4	1,478.8
9	876.1	600.0	1,476.1
10	900.1	599.2	1,499.3
11	898.0	600.1	1,498.1
Total	3,556.6	2,395.7	5,952.3

TABLE 57.—*Income and outgo of water and hydrogen—Metabolism experiment No. 8.*

Date.	Period.	Water.					
		(*a*) In food.	(*b*) In drink.	(*c*) In feces.	(*d*) In urine.	(*e*) In respiratory products.	(*f*) Apparent loss $a+b-(c+d+e)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m. to 7 a. m	1,266.4	1,478.8	49.5	3,120.1	1,136.3	—1,560.7
9-10	do	1,266.4	1,476.1	49.5	2,188.8	1,053.0	— 548.8
10-11	do	1,266.4	1,499.3	49.5	1,878.6	1,061.1	— 223.5
11-12	do	1,266.4	1,498.1	49.5	1,758.6	1,053.3	— 96.9
	Total, 4 days	5,065.6	5,952.3	198.0	8,946.1	4,303.7	—2,429.9
	Average, 1 day	1,266.4	1,488.1	49.5	2,236.5	1,075.9	— 607.5

Date.	Period.	Hydrogen.					
		(*g*) In food.	(*h*) In feces.	(*i*) In urine.	(*l*) Apparent gain $g-(h+i)$.	(*m*) Loss from water $(f\div 9)$.	(*n*) Total gain or loss $(l+m)$.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m. to 7 a. m	39.2	1.5	4.2	+ 33.5	—173.4	—139.9
9-10	do	39.2	1.4	3.8	+ 34.0	— 61.0	— 27.0
10-11	do	39.2	1.5	3.9	+ 33.8	— 24.8	+ 9.0
11-12	do	39.2	1.4	3.9	+ 33.9	— 10.8	+ 23.1
	Total, 4 days	156.8	5.8	15.8	+135.2	—270.0	—134.8
	Average, 1 day	39.2	1.5	4.0	+ 33.8	— 67.5	— 33.7

TABLE 58.—*Gain or loss of protein (N × 6.25), fat, and water—Metabolism experiment No. 8.*

Date.	Period.	(a) Nitrogen gained (+) or lost (—).	(b) Protein gained (+) or lost (—) (a × 6.25).	(c) Total carbon gained (+) or lost (—).	(d) Carbon in protein gained (+) or lost (—) (b × .53).	(e) Carbon in fat, etc., gained (+) or lost (—) c—d.	(f) Fat gained (+) or lost (—) e ÷ .765.
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m. to 7 a. m	—1.4	—8.7	+17.2	—4.6	+21.8	+ 28.5
9-10	.....do	+ .6	+3.8	+20.3	+2.0	+18.3	+ 23.9
10-11	.....do	+ .5	+3.1	+22.7	+1.6	+21.1	+ 27.6
11-12	.....do	+ .3	+1.8	+26.5	+1.0	+25.5	+ 33.3
	Total, 4 days	0	0	+86.7	0	+86.7	+113.3
	Average, 1 day	0	0	+21.7	0	+21.7	+ 28.3

Date.	Period.	(g) Total hydrogen gained (+) or lost (—).	(h) Hydrogen in protein gained (+) or lost (—) b × .07.	(i) Hydrogen in fat gained (+) or lost (—) f × .12.	(k) Hydrogen in water, etc., gained (+) or lost (—) g—(h+i).	(l) Water gained (+) or lost (—) (k × 9).
1897.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 8-9	7 a. m. to 7 a. m	—139.9	—0.6	+ 3.4	—142.7	—1,284.3
9-10	.....do	— 27.0	+ .3	+ 2.9	— 30.2	— 271.8
10-11	.....do	+ 9.0	+ .2	+ 3.3	+ 5.5	+ 49.5
11-12	.....do	+ 23.1	+ .1	+ 4.0	+ 19.0	+ 171.0
	Total, 4 days	—134.8	0	+13.6	—148.4	—1,335.6
	Average, 1 day	— 33.7	0	+ 3.4	— 37.1	— 333.9

TABLE 59.—*Income and outgo of energy—Metabolism experiment No. 8.*

Date.	Period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(d) Estimated heat of combustion of protein gained (+) or lost (—).	(e) Estimated heat of combustion of fat gained (+) or lost (—).	(f) Estimated energy of material oxidized in the body a—(b+c+d+e).	(g) Heat determined.	(h) Heat determined greater (+) or less (—) than estimated (f—g).	(i) Heat determined greater (+) or less (—) than estimated (h ÷ f).
1897.		*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per ct.*
Nov. 8-9	7 a. m. to 7 a. m	2,897	117	157	—50	+ 268	2,405	2,330	— 75	—3.1
9-10	.....do	2,897	117	152	+22	+ 225	2,381	2,284	— 97	—4.1
10-11	.....do	2,897	117	141	+18	+ 259	2,362	2,292	— 70	—3.0
11-12	.....do	2,897	117	160	+10	+ 313	2,297	2,240	— 57	—2.5
	Total, 4 days	11,588	468	610	0	+1,065	9,445	9,146	—299	—3.2
	Average, 1 day	2,897	117	153	0	+ 266	2,361	2,287	— 75	—3.2

The average daily income of energy in this experiment—i. e., the estimated heat of combustion of material actually oxidized in the body, averaged 2,361 calories per day, and the outgo—i. e., the heat given off from the body and measured, amounted to 2,287 calories. The measured outgo was thus 96.8 per cent of the theoretical income. This discrepancy of 3.2 per cent is larger than we are able to explain. We have been at pains to repeat a large number of the analyses of the food materials and excreta, although they had been previously made in duplicate or triplicate. Similar repetitions were made of a considerable number of the analyses of experiments Nos. 5, 6, and 7, but although the work was done with the greatest care the results failed to give data which would show any closer agreement of income and outgo of energy than the figures here given. The most plausible explanation, it has seemed to us, might be found in the faulty sampling of food materials, an assumption which is favored by the much more satisfactory results obtained in the succeeding experiments in which different methods of preparation and sampling of food were adopted. These new methods are described under the details of experiment No. 9.

DETAILS OF METABOLISM EXPERIMENT NO. 9.

Some of the details of this experiment have already been given in the previous publication above referred to and will not be repeated in this place. The subject entered the chamber on the evening of January 9, 1898, and the experiment proper began at 7 a. m. the following morning. During the interval between this and experiment No. 8, the method of preparation and sampling of food materials was so changed as to enable us to obtain, we believe, more accurate samples than had hitherto been possible. The method of sampling was that already described, in which the food materials were put up in jars before the beginning of the experiment (see page 19). The experiment was a rest experiment, and very nearly a repetition of experiment No. 8, but with a slight reduction of the amounts of protein and energy. No alcohol was included in the diet.

PREPARATION OF THE FOOD.

The beef was round steak, nearly freed from fat. It was passed through a meat chopper, by which it was cut in very small pieces and well mixed. This finely chopped meat was fried in a shallow, flat-bottomed pan over a gas flame until the whole was tolerably "well done," and had lost the distinctly reddish color. The juice which escaped in the cooking was discarded. The cooked meat was then thoroughly mixed, and portions appropriate for individual meals were weighed off, put in small glass jars, sterilized, and set aside in a cold place. The contents of two or more of the jars were used for analysis, as described on page 19. The others were used for the experiment. The meat kept well, the flavor was acceptable, and on the whole the method of preparation and sampling seemed satisfactory.

The bread was purchased at a local bakery. From an appropriate

number of loaves, weighing about 1¾ pounds each, the crust was trimmed off and discarded. The object in removing the crust was to avoid error due to the introduction of varying proportion of this drier protein into the different jars. The crumb was cut into pieces small enough to pass easily into glass jars, and well mixed. Portions of appropriate weight were put in glass jars, sealed, sterilized, and set aside in a cold place. The total quantity for a day's ration was put sometimes in one jar and sometimes in two. The contents of two or more jars were used for analysis. The bread kept well and was palatable.

Butter in sufficient amounts for the whole experiment, including samples for analysis, was purchased from a local creamery, and was put up in small glass pomade jars in such quantities that one jar furnished sufficient butter for one day. The specimens thus prepared were kept in a cool place. Separator milk was used in this experiment owing to the greater uniformity in the content of fat as compared with whole milk, this varying but little from 0.1 per cent. It was purchased fresh each day, and a composite sample made up of aliquot portions of the milk of each day was taken for analysis. The maize and wheat breakfast foods were purchased in quantity sufficient for several experiments and well mixed. The amounts required for each meal were placed in glass jars and set aside until needed. One analysis of the maize and one of the wheat product thus served for several experiments.

Ginger snaps were purchased in sufficient quantity for one experiment and in amounts appropriate for individual meals and were put in glass jars as was done with other food materials. "Granulated" sugar was purchased in quantity sufficient for several experiments and kept in a closed vessel. Amounts for a day were placed in glass bottles, and the subject used as nearly as he could judge the amounts indicated in the menu for each meal. The coffee infusion was prepared as explained in the description of experiment No. 5.

The menu, daily programme, and summary of the subject's observations in the calorimeter are given in the following tables:

TABLE 60.—*Daily menu—Metabolism experiment No. 9.*

Menu.	Grams.	Menu.	Grams.
BREAKFAST.		DINNER—continued.	
Beef, fried	100	Wheat breakfast food	50
Butter	15	Sugar	25
Skim milk	160	Coffee	300
Bread	25	SUPPER.	
Maize breakfast food	50	Butter	15
Sugar	25	Skim milk	390
Coffee	300	Bread	25
DINNER.		Wheat breakfast food	75
Beef, fried	150	Ginger snaps	60
Butter	20	Sugar	30
Skim milk	210	Coffee	300
Bread	50		

TABLE 61.—*Daily programme—Metabolism experiment No. 9.*

7.00 a.m.	Rise, pass urine, weigh self stripped, collect drip, weigh absorbers.	6.30 p.m.	Supper.
7.45 a.m.	Breakfast.	7.00 p.m.	Pass urine, collect drip, weigh absorbers.
10.30 a.m.	Drink 200 grams water.	10.00 p.m.	Drink 200 grams water, weigh self stripped, take cap off food aperture, retire.
1.00 p.m.	Pass urine, collect drip, weigh absorbers.	1.00 a.m.	Pass urine.
1.30 p.m.	Dinner.		
3.30 p.m.	Drink 200 grams water.		

TABLE 62.—*Summary of the diary—Metabolism experiment No. 9.*

Time.	Weight of subject.		Pulse rate per minute.	Temperature.	Hygrometer.	
	Without clothes.	With clothes.			Dry bulb.	Wet bulb.
1898.	*Kilograms.*	*Kilograms.*		°*F.*	°*C.*	°*C.*
Jan. 10, 7.00 a.m	68.42				21.7	17.0
10, 8.30 a.m		72.83	73	98.4		
10, 1.25 p.m					21.6	17.4
10, 4.25 p.m					21.5	17.4
10, 5.00 p.m			69	98.3		
10, 7.00 p.m					21.6	17.2
10, 10.00 p.m	[1]69.20					
10, 10.15 p.m			59	98.0	21.5	17.4
11, 7.00 a.m	68.26					
11, 7.30 a.m			58	96.1	21.4	16.8
11, 10.30 a.m					21.5	16.9
11, 1.00 p.m					21.5	16.8
11, 4.20 p.m					21.4	16.8
11, 7.20 p.m					21.4	16.8
11, 10.00 p.m	68.53		72	97.9	22.1	17.7
12, 7.00 a.m	67.81					
12, 7.30 a.m			62	96.4	21.4	16.2
12, 11.00 a.m					21.4	16.4
12, 1.00 p.m			67	97.9	21.8	16.7
12, 3.30 p.m					21.5	16.4
12, 6.00 p.m					21.5	16.4
12, 10.00 p.m	68.65		65	98.1	21.7	16.8
13, 7.00 a.m	68.00					
13, 7.30 a.m			62	97.4	21.3	16.4
13, 10.35 a.m					21.5	16.6
13, 1.00 p.m			70	97.9	21.7	16.4
13, 4.00 p.m					21.4	16.4
13, 6.55 p.m					21.6	16.8
13, 10.00 p.m	68.72		72	98.4	21.5	16.7
14, 7.00 a.m	67.20				21.7	16.6

[1] It seems quite probable that this subject recorded his weight erroneously at this time.

The weights and composition of the daily food are given in Table 63, and those for the feces and urine in Tables 64 and 65.

TABLE 63.—*Weight, composition, and heats of combustion of foods—Metabolism experiment No. 9.*

Laboratory No.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2835	Beef, fried	250	168.3	64.0	13.5	....	10.25	40.88	5.63	482
2836	Skim milk	758	687.5	25.0	.8	39.4	3.94	30.62	4.32	298
2833	Butter	50	5.1	.6	42.4	....	.10	31.34	5.13	388
2834	Bread	100	44.7	8.4	.2	44.3	1.34	24.53	3.54	240
2830	Wheat breakfast food	125	9.4	12.4	2.0	97.1	1.98	51.65	7.22	509
2829	Ginger snaps ...	60	3.2	3.6	5.7	45.4	.58	26.67	3.89	261
2832	Sugar	80	....	....	....	80.0	....	33.68	5.18	317
2831	Maize breakfast food	50	2.8	5.6	4.4	35.6	.89	22.17	3.22	222
	Total	1,473	921.0	119.6	69.0	341.8	19.08	261.54	38.13	2,717

TABLE 64.—*Weight, composition, and heats of combustion of fresh feces—Metabolism experiment No. 9.*

Laboratory No.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion (determined).
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2838	Total, 4 days....	424.0	309.1	31.4	16.5	48.4	5.04	53.42	7.38	569
	Average, 1 day..	106.0	77.3	7.9	4.1	12.1	1.26	13.36	1.85	142

TABLE 65.—*Amounts and composition of urine—Metabolism experiment No. 9.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.		Carbon.[1]	
1898.		*Grams.*		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*
Jan. 10–11	7 a. m. to 1 p. m	341.1	1.021	1.26	4.30		
	1 p. m. to 7 p. m	686.5	1.015	.85	5.84		
	7 p. m. to 1 a. m	661.8	1.013	.86	5.69		
	1 a. m. to 7 a. m	165.9	1.024	1.76	2.92		
	Total	1,855.3		(1.01)	18.75		12.79
	Total by composite	1,855.3		1.03	19.11		
11–12	7 a. m. to 1 p. m	379.5	1.019	1.15	4.36		
	1 p. m. to 7 p. m	676.8	1.015	.88	5.96		
	7 p. m. to 1 a. m	774.8	1.012	.76	5.89		
	1 a. m. to 7 a. m	146.5	1.025	1.74	2.55		
	Total	1,977.6		(.95)	18.76		12.80
	Total by composite	1,977.6		.96	18.98		
12–13	7 a. m. to 1 p. m	371.9	1.018	1.08	4.02		
	1 p. m. to 7 p. m	337.3	1.025	1.53	5.16		
	7 p. m. to 1 a. m	652.3	1.016	.99	6.46		
	1 a. m. to 7 a. m	149.1	1.024	1.77	2.64		
	Total	1,510.6		(1.21)	18.28		12.47
	Total by composite	1,510.6		1.19	17.98		
13–14	7 a. m. to 1 p. m	319.1	1.019	1.29	4.12		
	1 p. m. to 7 p. m	272.4	1.027	1.68	4.58		
	7 p. m. to 1 a. m	599.4	1.015	1.06	6.35		
	1 a. m. to 7 a. m	168.0	1.022	1.69	2.84		
	Total	1,358.9		(1.32)	17.89		12.21
	Total by composite	1,358.9		1.28	17.39		
	Total for 4 days by periods	6,702.4			73.68		
	Composite, 4 days	6,702.4	1.017	1.07	71.72	0.75	50.27
14–15	7 a. m. to 1 p. m	215.7	1.028	1.72	3.71		
	1 p. m. to 7 p. m	208.5	1.032	1.52	3.17		
	7 p. m. to 1 a. m	340.5	1.030	2.01	6.84		
	1 a. m. to 7 a. m	194.0	1.028	1.16	2.25		
	Total	958.7			15.97		
15–16	7 a. m. to 1 p. m	201.1		1.54	3.10		
	1 p. m. to 7 p. m	262.0		1.44	3.77		
	7 p. m. to 1 a. m	404.3		1.51	6.10		
	1 a. m. to 7 a. m	222.9		1.63	3.63		
	Total	1,090.3			16.60		

[1] The method of drying the urine in this experiment was as explained on page 22. The urine was evaporated to dryness on a water bath; the nitrogen was determined in the fresh urine and in the dried residue, thus giving data for calculating the amount decomposed during the drying and given off as ammonium carbonate. The calculations are too detailed to be given here. It will suffice to say that it was estimated that in the process of drying 0.17 gram of urea was decomposed from every 100 grams fresh urine. This urea would contain 0.034 gram of carbon. Adding this weight of carbon to that found in the dried residue would make the percentage of carbon in the water-free urine 16.89 instead of 16.76, as actually found. Although the correction is small, it is taken into account in the value used for the percentage of carbon in the fresh urine.

TABLE 65.—*Amounts and composition of urine—Metabolism experiment No. 9*—Cont'd.

Date.	Period.	Hydrogen.		Water.		Heats of combustion.	
						Per gram.	Total.
1898.		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
Jan. 10-11	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.41		1,784.3		
	Total by composite					0.082	152
11-12	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.41		1,906.6		
	Total by composite					.081	160
12-13	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.33		1,441.5		
	Total by composite					.095	143
13-14	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total		3.26		1,291.2		
	Total by composite					.102	139
	Total for 4 days, by periods						594
	Composite, 4 days	0.20	13.41	95.84	6,423.6	.089	597
14-15	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total						
15-16	7 a. m. to 1 p. m						
	1 p. m. to 7 p. m						
	7 p. m. to 1 a. m						
	1 a. m. to 7 a. m						
	Total						

Table 66 shows the results of the determinations of residual carbon dioxid and water within the apparatus and the changes in weight in the absorbers and the drip. The amount of drip was only 70 grams for the whole experiment, and this accumulated on the last day. In the calculations of the tables it has been assumed that it collected uniformly during the last four periods of the experiment, though it is probable that the accumulation was less during the period of sleep than at other times.

TABLE 66.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 9.*

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (—) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (—) over preceding period.	Water. Change in weight of absorbers. Gain (+) or loss (—).	Water. Drip from absorbers.	Water. Total amount gained (+) or lost (—) during the period.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 10-11	7 a. m	26.9		44.9				
	1 p. m	30.0	+ 3.1	31.4	—13.5	+14		+ 0.5
	7 p. m	44.9	+14.9	46.7	+15.3	+22		+37.3
	1 a. m	30.2	—14.7	49.8	+ 3.1	— 9		— 5.9
	7 a. m	27.7	— 2.5	42.9	— 6.9	— 9		—15.9
	Total		+ .8		— 2.0	+18		+16.0
11-12	1 p. m	39.0	+11.3	43.4	+ .5	+ 3		+ 3.5
	7 p. m	44.3	+ 5.3	45.6	+ 2.2	— 1		+ 1.2
	1 a. m	31.7	—12.6	50.2	+ 4.6	—11		— 6.4
	7 a. m	26.5	— 5.2	40.5	— 9.7	—10		—19.7
	Total		— 1.2		— 2.4	—19		—21.4
12-13	1 p. m	45.7	+19.2	44.3	+ 3.8	+13		+16.8
	7 p. m	46.0	+ .3	44.8	+ .5	+ 4		+ 4.5
	1 a. m	35.4	—10.6	55.3	+10.5	— 4		+ 6.5
	7 a. m	27.3	— 8.1	40.2	—15.1	— 4		—19.1
	Total		+ .8		— .3	+ 9		+ 8.7
13-14	1 p. m	48.5	+21.2	44.1	+ 3.9	+11	+17.6	+32.5
	7 p. m	48.8	+ .3	46.4	+ 2.3	+ 7	+17.5	+26.8
	1 a. m	34.8	—14.0	51.8	+ 5.4	— 5	+17.5	+17.9
	7 a. m	25.7	— 9.1	40.2	—11.6	— 6	+17.5	— .1
	Total		— 1.6			+ 7	+70.1	+77.1
	Total for 4 days		— 1.2		— 4.7	+15	+70.1	+80.4

The tables showing the experimental data for carbon dioxid and water vapor in the ventilating air current have already been given in detail in a previous publication of this series,[1] and only the total amounts for each day are here shown.

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 63, p. 79.

TABLE 67.—*Summary of carbon dioxid and water in ventilating air current—Metabolism experiment No. 9.*

Date.	Period.	Volume of ventilating air current.	Carbon dioxid. Total excess in outgoing air.	Carbon dioxid. Correction for residual amount in apparatus.	Carbon dioxid. Corrected amount exhaled by subject.	Total weight of carbon exhaled in carbon dioxid.	Water. Total excess in outgoing air.	Water. Condensed in freezers.	Water. Correction for residual amount in chamber.	Water. Total amount exhaled.
1898.		*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 10–11	7 a. m. to 7 a. m.	104, 549	830. 3	+0. 8	831. 1	226. 7	43. 1	898. 8	+16. 0	957. 9
11–12	do	105, 598	814. 6	—1. 2	813. 4	221. 8	48. 3	864. 8	—21. 4	891. 7
12–13	do	104, 144	808. 5	+ . 8	809. 3	220. 7	47. 1	850. 0	+ 8. 7	905. 8
13–14	do	104, 542	827. 6	—1. 6	826. 0	225. 3	46. 9	885. 5	+77. 1	1, 009. 5
	Total, 4 days	418, 833	3, 281. 0	—1. 2	3, 279. 8	894. 5	185. 4	3, 499. 1	+80. 4	3, 764. 9
	Average, 1 day	104, 708			820. 0	223. 6				941. 2

Table 68 summarizes the calorimetric measurements of which the details are given in the previous publication referred to.

TABLE 68.—*Summary of calorimetric measurements—Metabolism experiment No. 9.*

Date.	Period.	Heat measured.	Change of temperature of calorimeter.	Capacity correction.	Correction due to temperature of food and dishes.	Water vaporized.	Equivalent heat of water vaporized.	Total heat determined.
1898.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Jan. 10–11	7 a. m. to 7 a. m.	1, 854. 5	—0. 08	—4. 8	— 59. 7	939. 9	556. 4	2, 346. 4
11–12	do	1, 766. 5	+ . 12	+7. 2	— 51. 2	910. 7	539. 1	2, 261. 6
12–13	do	1, 819. 4	+ . 08	+4. 8	— 53. 0	896. 8	530. 9	2, 302. 1
13–14	do	1, 827. 9	— . 06	—3. 6	— 50. 5	932. 4	552. 0	2, 325. 8
	Total, 4 days	7, 268. 3	+ . 06	+3. 6	—214. 4	3, 679. 8	2, 178. 4	9, 235. 9
	Average, 1 day	1, 817. 1						2, 309. 0

In the following tables, 69 to 72, are shown the income and outgo of nitrogen, carbon, hydrogen, protein, fat, water, and energy in this experiment:

TABLE 69.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 9.*

Date.	Period.	Nitrogen. (a) In food.	(b) In feces.	(c) In urine.	(d) Gain (+) or loss (—) $a-(b+c)$.	Carbon. (e) In food.	(f) In feces.	(g) In urine.	(h) In respiratory products.	(k) Gain (+) or loss (—) $e-(f+g+h)$.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 10–11	7 a.m. to 7 a.m.	19.1	1.2	18.7	—0.8	261.5	13.3	12.8	226.7	+ 8.7
11–12	.....do	19.1	1.3	18.8	—1.0	261.6	13.4	12.8	221.8	+13.6
12–13	.....do	19.1	1.2	18.3	— .4	261.5	13.3	12.5	220.7	+15.0
13–14	.....do	19.1	1.3	17.9	— .1	261.6	13.4	12.2	225.3	+10.7
	Total, 4 days..	76.4	5.0	73.7	—2.3	1,046.2	53.4	50.3	894.5	+48.0
	Average, 1 day	19.1	1.3	18.4	— .6	261.6	13.4	12.6	223.6	+12.0

The record of the water actually consumed each day is given in the following table:

Record of drinking water and coffee—Metabolism experiment No. 9.

Date.	Coffee infusion.	Drinking water.	Total drink.
	Grams.	*Grams.*	*Grams.*
Jan. 10	892.6	600	1,492.6
11	889.7	400	1,289.7
12	899.3	400	1,299.3
13	899.6	400	1,299.6
Total	3,581.2	1,800	5,381.2

TABLE 70.—*Income and outgo of water and hydrogen—Metabolism experiment No. 9.*

Date.	Period.	Water. (a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.	(f) Apparent loss $a+b-(c+d+e)$.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 10–11	7 a. m. to 7 a. m	921.0	1,492.6	77.3	1,784.3	957.9	— 405.9
11–12	.....do	921.0	1,289.7	77.3	1,906.6	891.7	— 664.9
12–13	.....do	921.0	1,299.3	77.3	1,441.5	905.9	— 204.4
13–14	.....do	921.0	1,299.6	77.3	1,291.2	1,009.5	— 157.4
	Total, 4 days	3,684.0	5,381.2	309.2	6,423.6	3,765.0	—1,432.6
	Average, 1 day	921.0	1,345.3	77.3	1,605.9	941.3	— 358.2

Date.	Period.	Hydrogen. (g) In food.	(h) In feces.	(i) In urine.	(l) Apparent gain $g-(h+i)$.	(m) Loss from water $(f\div 9)$.	(n) Total gain (+) or loss (—) $(l+m)$.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 10–11	7 a. m. to 7 a. m	38.1	1.8	3.4	+ 32.9	— 45.1	—12.2
11–12	.....do	38.1	1.9	3.4	+ 32.8	— 73.9	—41.1
12–13	.....do	38.1	1.8	3.3	+ 33.0	— 22.7	+10.3
13–14	.....do	38.1	1.9	3.3	+ 32.9	— 17.5	+15.4
	Total, 4 days	152.4	7.4	13.4	+131.6	—159.2	—27.6
	Average, 1 day	38.1	1.9	3.4	+ 32.9	— 39.8	— 6.9

TABLE 71.—*Gain or loss of protein (N× 6.25), fat, and water—Metabolism experiment No. 9.*

Date.	Period.	(a) Nitrogen gained (+) or lost (—).	(b) Protein gained (+) or lost (—) $(a\times 6.25)$.	(c) Total carbon gained (+) or lost (—).	(d) Carbon in protein gained (+) or lost (—) $(b\times .53)$.	(e) Carbon in fat, etc., gained (+) or lost (—) $(c-d)$.	(f) Fat gained (+) or lost (—) $(e\div .765)$.
1898.		*Grams.*	*Grams*	*Grams.*	*Grams.*	*Grams.*	*Grams,*
Jan. 10–11	7 a. m. to 7 a. m	— .8	— 5.0	+ 8.7	—2.7	+11.4	+14.9
11–12	.....do	—1.0	— 6.3	+13.6	—3.3	+16.9	+22.1
12–13	.....do	— .4	— 2.5	+15.0	—1.3	+16.3	+21.3
13–14	.....do	— .1	— .6	+10.7	— .3	+11.0	+14.4
	Total, 4 days	—2.3	—14.4	+48.0	—7.6	+55.6	+72.7
	Average, 1 day	— .6	— 3.6	+12.0	—1.9	+13.9	+18.2

TABLE 71.—*Gain or loss of protein (N×6.25), fat, and water—Metabolism experiment No. 9*—Continued.

Date.	Period.	(g) Total hydrogen gained (+) or lost (—).	(h) Hydrogen in protein gained (+) or lost (—) (b×.07).	(i) Hydrogen in fat gained (+) or lost (—) (f×.12).	Hydrogen in water, etc., gained (+) or lost (—) g—(h+i).	(l) Water gained (+) or lost (—) (k×9).
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 10-11	7 a. m. to 7 a. m.	—12.2	— .4	+1.8	—13.6	—122.4
11-12	....do	—41.1	— .4	+2.6	—43.3	—389.7
12-13	....do	+10.3	— .2	+2.6	+ 7.9	+ 71.1
13-14	....do	+15.4	.0	+1.7	+13.7	+123.3
	Total, 4 days	—27.6	—1.0	+8.7	—35.3	—317.7
	Average, 1 day	— 6.9	— .3	+2.2	— 8.8	— 79.4

TABLE 72.—*Income and outgo of energy—Metabolism experiment No. 9.*

Date.	Period.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(d) Estimated heat of combustion of protein gained (+) or lost (—).	(e) Estimated heat of combustion of fat gained (+) or lost (—).	(f) Estimated energy of material oxidized in the body, a—(b+c+d+e).	(g) Heat determined.	(h) Heat determined greater (+) or less (—) than estimated (f—g).	(i) Heat determined greater (+) or less (—) than estimated (h÷f).
1898.		*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Jan. 10-11	7 a. m. to 7 a. m.	2,717	142	152	—29	+140	2,312	2,346	+ 34	+1.5
11-12	....do	2,717	142	160	—36	+208	2,243	2,262	+ 19	+ .8
12-13	....do	2,717	142	143	—14	+200	2,246	2,302	+ 56	+2.5
13-14	....do	2,717	142	139	— 4	+135	2,305	2,326	+ 21	+ .9
	Total, 4 days	10,868	568	594	—83	+683	9,106	9,236	+130	+1.4
	Average, 1 day	2,717	142	149	—21	+171	2,277	2,309	+ 32	+1.4

The average daily income of energy in this experiment—i. e., the estimated heat of combustion of material actually oxidized in the body—averaged 2,277 calories per day, and the outgo—i. e., the heat given off from the body and measured—amounted to 2,309 calories. The measured outgo was thus 1.4 per cent larger than the theoretical income.

It is noticeable that with change in the method of sampling an agreement of income and outgo is closer than in experiments Nos. 5 and 6, and, furthermore, that the measured energy of outgo slightly exceeds the theoretical energy of income.

DETAILS OF EXPERIMENT NO. 10.

This experiment was intended to be a duplicate as nearly as practicable of experiment No. 9, except that a portion of the fats and carbohydrates of the diet sufficient to furnish approximately 500 calories of energy per day were replaced by an isodynamic amount of alcohol. The amount of protein was the same as in the preceding experiment.

The subject entered the apparatus on the evening of February 14, 1898, and the experiment proper began at the usual time, 7 o'clock the next morning. The alcohol was the same in kind and amount and administered in the same way as in experiment No. 7 (see p. 61), and the experience there gained was used to advantage in improving the arrangements for this experiment. The amount of alcohol eliminated as such from the body was determined by the method described on page 27, with results as shown in Table 83.

The daily menu, programme, and summary of the diary and the determined and computed results of income and outgo are shown in Tables 73–83.

TABLE 73.—*Daily menu—Metabolism experiment No. 10.*

Menu.	Grams.	Menu.	Grams.
BREAKFAST.		DINNER—continued.	
Beef, fried	120	Bread	50
Butter	5	Coffee and alcohol	200
Skim milk	160	SUPPER.	
Bread	50	Bread	25
Maize breakfast food	50	Wheat breakfast food	50
Sugar	10	Butter	5
Coffee and alcohol	175	Skim milk	390
DINNER.		Ginger snaps	60
Beef, fried	150	Sugar	15
Butter	5	Coffee and alcohol	200
Skim milk	200		

Besides the coffee and alcohol consumed at the regular meals, 125 grams was consumed in the middle of the forenoon, 125 grams in the middle of the afternoon, and 115 grams just before retiring.

TABLE 74.—*Daily programme—Metabolism experiment No. 10.*

7.00 a. m.	Rise, pass urine, weigh self stripped, collect drip, weigh absorbers.	3.30 p. m.	Drink 125 grams alcohol and coffee.
7.45 a. m.	Breakfast (including 175 grams alcohol and coffee).	6.30 p. m.	Supper (including 200 grams alcohol and coffee).
10.30 a. m.	Drink 125 grams alcohol and coffee.	7.00 p. m.	Pass urine, collect drip, weigh absorbers.
1.00 p. m.	Pass urine, collect drip, weigh absorbers.	10.00 p. m.	Drink remainder of alcohol and coffee, weigh self stripped, take cap off food aperture, retire.
1.30 p. m.	Dinner (including 200 grams alcohol and coffee).	1.00 a. m.	Pass urine.

TABLE 75.—*Summary of the diary—Metabolism experiment No. 10.*

Time.	Weight of subject.		Pulse rate per minute.	Temperature.	Hygrometer.	
	Without clothes.	With clothes.			Dry bulb.	Wet bulb.
1898.	*Kilograms.*	*Kilograms.*		*°F.*	*°C.*	*°C.*
Feb. 15, 7.00 a. m	67.45	71.11				
15, 7.45 a. m					21.5	16.6
15, 8.30 a. m			59	97.4		
15, 10.45 a. m					21.5	16.6
15, 1.00 p. m			65	98.8		
15, 1.45 p. m					21.6	16.8
15, 6.00 p. m			67	98.8	21.5	16.7
15, 10.00 p. m	68.51		67	99.0	21.9	17.2
16, 7.00 a. m	67.87					
16, 7.30 a. m			59	96.8	21.7	16.5
16, 11.00 a. m			66	98.2	21.4	16.2
16, 2.30 p. m			69	99.0	21.6	16.6
16, 6.00 p. m			71	99.4	21.8	17.0
16, 9.30 p. m			71	99.0	21.7	17.6
16, 10.00 p. m	68.59					
17, 7.00 a. m	67.81					
17, 7.30 a. m			66	96.4	21.4	16.3
17, 11.00 a. m			70	98.8	21.5	16.4
17, 2.30 p. m			68	99.0	21.5	16.6
17, 6.00 p. m			71	99.0	21.5	16.4
17, 9.30 p. m			70	98.6	21.6	16.8
17, 10.00 p. m	68.23					
18, 7.00 a. m	67.52					
18, 7.30 a. m			56	96.4	21.5	16.2
18, 11.00 a. m			85	98.8	21.8	16.6
18, 2.30 p. m			70	98.6	21.5	16.8
18, 6.00 p. m			64	98.4	22.0	17.6
18, 9.30 p. m			69	98.6	22.2	18.0
18, 10.00 p. m	68.12					
19, 7.00 a. m	67.59	71.21			22.0	17.2

TABLE 76.—*Weight, composition, and heats of combustion of foods—Metabolism experiment No. 10.*

Laboratory number.	Food material.	Weight per day.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion determined.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2839	Beef	270	182.5	73.4	8.9	....	11.72	44.04	6.32	490
2840	Wheat breakfast food	50	3.6	5.4	.7	39.7	.88	20.60	3.02	203
2841	Ginger snaps	60	2.6	3.5	3.7	48.5	.55	25.67	3.88	255
2842	Maize breakfast food	50	2.5	5.9	4.1	36.7	.94	22.25	3.25	222
2843	Butter	15	1.5	.1	13.1	....	.02	9.66	1.50	120
2844	Bread	125	51.4	10.4	.3	61.2	1.66	32.69	4.80	319
2846	Skim milk	750	678.0	24.8	.8	41.3	3.98	31.13	4.58	311
......	Sugar	70	....	....	....	70.0	....	29.47	4.54	277
	Total	1,390	922.1	123.5	31.6	297.4	19.75	215.51	31.89	2,197
......	Alcohol	72.5	....	....	....	[1] 123.0	....	37.82	9.46	512
	Total	....	922.1	123.5	31.6	420.4	19.75	253.33	41.35	2,709

[1] One gram alcohol calculated as isodynamically equivalent to 1.7 grams carbohydrates, this being the ratio of the heats of combustion (4.1 : 7.1).

TABLE 77.—*Weight, composition, and heats of combustion of fresh feces—Metabolism experiment No. 10.*

Laboratory number.		Weight.	Water.	Protein.	Fat.	Carbohydrates.	Nitrogen.	Carbon.	Hydrogen.	Heats of combustion determined.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
2848	Total, 4 days	351	249.2	34.4	14.7	35.8	5.51	47.18	6.39	508
......	Average, 1 day	87.8	62.3	8.6	3.7	9.0	1.38	11.80	1.60	127

TABLE 78.—*Amounts and composition of urine—Metabolism experiment No. 10.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.		Carbon.	
1898.		*Grams.*		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*
Feb. 15–16	7 a. m. to 1 p. m	263.6	1.027	1.73	4.56		
	1 p. m. to 7 p. m	332.6	1.029	1.78	5.92		
	7 p. m. to 1 a. m	370.1	1.026	1.61	5.96		
	1 a. m. to 7 a. m	149.3	1.028	2.21	3.30		
	Total	1,115.6			19.74		13.70
	Total by composite	1,115.6	1.027	1.76	19.63		
16–17	7 a. m. to 1 p. m	276.6	1.027	1.81	5.01		
	1 p. m. to 7 p. m	434.9	1.024	1.53	6.65		
	7 p. m. to 1 a. m	468.3	1.020	1.24	5.81		
	1 a. m. to 7 a. m	153.0	1.027	2.03	3.11		
	Total	1,332.8			20.58		14.28
	Total by composite	1,332.8	1.023	1.56	20.79		
17–18	7 a. m. to 1 p. m	285.8	1.026	1.67	4.77		
	1 p. m. to 7 p. m	433.1	1.018	1.12	4.85		
	7 p. m. to 1 a. m	819.7	1.014	.85	6.97		
	1 a. m. to 7 a. m	163.5	1.024	1.69	2.76		
	Total	1,702.1			19.35		13.43
	Total by composite	1,702.1	1.018	1.15	19.57		
18–19	7 a. m. to 1 p. m	249.0	1.024	1.70	4.23		
	1 p. m. to 7 p. m	452.2	1.021	1.29	5.83		
	7 p. m. to 1 a. m	325.8	1.026	1.52	4.95		
	1 a. m. to 7 a. m	166.4	1.024	1.85	3.08		
	Total	1,193.4			18.09		12.56
	Total by composite	1,193.4	1.023	1.52	18.14		
	Total, 4 days, by periods	5,343.9			77.76		
	Composite, 4 days	5,343.9		1.45	77.49	1.01	53.97
19–20	7 a. m. to 1 p. m	184.5		1.80	3.32		
	1 p. m. to 7 p. m	198.8		1.80	3.58		
	7 p. m. to 1 a. m	332.3		1.42	4.72		
	1 a. m. to 7 a. m	279.0		1.40	3.91		
	Total	994.6			15.53		
20–21	7 a. m. to 1 p. m	220.5		1.29	2.84		
	1 p. m. to 7 p. m	223.6		1.20	2.68		
	7 p. m. to 1 a. m	389.4		1.51	5.88		
	1 a. m. to 7 a. m	294.8		.76	2.24		
	Total	1,128.3			13.64		

TABLE 78.—*Amounts and composition of urine—Metabolism experiment No. 10*—Cont'd.

Date.	Period.	Hydrogen.		Water.		Heats of combustion.	
						Per gram.	Total.
1898.		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Calories.*	*Calories.*
Feb. 15–16	7 a. m. to 1 p. m	....	....	....	....	....	....
	1 p. m. to 7 p. m	....	....	....	....	....	....
	7 p. m. to 1 a. m	....	....	....	....	....	....
	1 a. m. to 7 a. m	....	....	....	....	....	....
	Total	....	3.26	....	1,049.8	....	....
	Total by composite	....	....	....	....	0.126	140
16–17	7 a. m. to 1 p. m	....	....	....	....	....	....
	1 p. m. to 7 p. m	....	....	....	....	....	....
	7 p. m. to 1 a. m	....	....	....	....	....	....
	1 a. m. to 7 a. m	....	....	....	....	....	....
	Total	....	3.40	....	1,264.2	....	....
	Total by composite	....	....	....	....	.122	162
17–18	7 a. m. to 1 p. m	....	....	....	....	....	....
	1 p. m. to 7 p. m	....	....	....	....	....	....
	7 p. m. to 1 a. m	....	....	....	....	....	....
	1 a. m. to 7 a. m	....	....	....	....	....	....
	Total	....	3.19	....	1,637.6	....	....
	Total by composite	....	....	....	....	.087	148
18–19	7 a. m. to 1 p. m	....	....	....	....	....	....
	1 p. m. to 7 p. m	....	....	....	....	....	....
	7 p. m. to 1 a. m	....	....	....	....	....	....
	1 a. m. to 7 a. m	....	....	....	....	....	....
	Total	....	2.98	....	1,133.1	....	....
	Total by composite	....	....	....	....	.116	139
	Total, 4 days, by periods	....	....	....	....	....	589
	Composite, 4 days	0.24	12.83	95.15	5,084.7	.110	588
19–20	7 a. m. to 1 p. m	....	....	....	....	....	....
	1 p. m. to 7 p. m	....	....	....	....	....	....
	7 p. m. to 1 a. m	....	....	....	....	....	....
	1 a. m. to 7 a. m	....	....	....	....	....	....
	Total	....	....	....	....	....	....
20–21	7 a. m. to 1 p. m	....	....	....	....	....	....
	1 p. m. to 7 p. m	....	....	....	....	....	....
	7 p. m. to 1 a. m	....	....	....	....	....	....
	1 a. m. to 7 a. m	....	....	....	....	....	....
	Total	....	....	....	....	....	....

TABLE 79.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period, and the corresponding gain or loss—Metabolism experiment No. 10.*

Date.	End of period.	Carbon dioxid. Total amount in chamber.	Carbon dioxid. Gain (+) or loss (—) over preceding period.	Water. Total amount of vapor remaining in chamber.	Water. Gain (+) or loss (—) over preceding period.	Water. Change in weight of absorbers—gain (+) or loss (—).	Water. Drip from absorbers.	Water. Total amount gained (+) or lost (—) during the period.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15–16	7 a. m.	23.9	....	40.2	....	....	....	....
	1 p. m.	36.0	+12.1	41.9	+ 1.7	+80	....	+ 81.7
	7 p. m.	39.6	+ 3.6	44.5	+ 2.6	+15	....	+ 17.6
	1 a. m.	28.5	—11.1	48.8	+ 4.3	—13	....	— 8.7
	7 a. m.	26.0	— 2.5	39.3	— 9.5	—13	....	— 22.5
	Total	....	+ 2.1	....	— .9	+69	....	+ 68.1
16–17	1 p. m.	41.2	+15.2	41.9	+ 2.6	+23	....	+ 25.6
	7 p. m.	42.5	+ 1.3	43.6	+ 1.7	+ 2	....	+ 3.7
	1 a. m.	30.5	—12.0	50.8	+ 7.2	— 3	....	+ 4.2
	7 a. m.	24.3	— 6.2	38.5	—12.3	— 4	....	— 16.3
	Total	....	— 1.7	....	— .8	+18	....	+ 17.2
17–18	1 p. m.	38.9	+14.6	40.1	+ 1.6	+ 9	....	+ 10.6
	7 p. m.	43.7	+ 4.8	43.4	+ 3.3	+ 3	....	+ 6.3
	1 a. m.	30.7	—13.0	44.2	+ .8	— 7	....	— 6.2
	7 a. m.	24.5	— 6.2	37.5	— 6.7	— 8	....	— 14.7
	Total	....	+ .2	....	— 1.0	— 3	....	— 4.0
18–19	1 p. m.	39.4	+14.9	43.7	+ 6.2	+11	7	+ 24.2
	7 p. m.	43.2	+ 3.8	46.3	+ 2.6	+16	6	+ 24.6
	1 a. m.	35.9	— 7.3	49.6	+ 3.3	— 9	6	+ .3
	7 a. m.	26.3	— 9.6	40.7	— 8.9	—10	6	— 12.9
	Total	....	+ 1.8	....	+ 3.2	+ 8	25	+ 36.2
	Total for 4 days	....	+ 2.4	....	+ .5	+92	25	+117.5

TABLE 80.—*Record of carbon dioxid in ventilating air current—Metabolism experiment No. 10.*

Date.	Period.	(a) Volume of ventilating air current.	Carbon dioxid per liter— (b) In incoming air.	(c) In outgoing air.	(d) Excess in outgoing air (c—b).	(e) Total excess in outgoing air (d×a).	(f) Correction for carbon dioxid in apparatus.	(g) Corrected weight for carbon dioxid exhaled by subject (e+f).	(h) Total weight carbon exhaled in carbon dioxid ($g \times \frac{3}{11}$).
1898.		*Liters.*	*Mg.*	*Mgs.*	*Mgs.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15-16	7 a. m. to 1 p. m	26,823	0.610	8.349	7.739	207.6	+12.1	219.7	59.9
	1 p. m. to 7 p. m	27,192	.567	8.199	7.632	207.6	+ 3.6	211.2	57.6
	7 p. m. to 1 a. m	27,655	.547	7.972	7.425	205.2	—11.1	194.1	52.9
	1 a. m. to 7 a. m	27,705	.569	5.547	4.978	137.9	— 2.5	135.4	36.9
	Total	109,375	....	....	....	758.3	+ 2.1	760.4	207.3
16-17	7 a. m. to 1 p. m	26,458	.634	8.597	7.963	210.7	+15.2	225.9	61.6
	1 p. m. to 7 p. m	26,866	.698	9.255	8.557	229.9	+ 1.3	221.2	60.3
	7 p. m. to 1 a. m	27,228	.738	8.518	7.780	211.8	—12.0	209.8	57.2
	1 a. m. to 7 a. m	27,114	.632	5.763	5.131	139.1	— 6.2	132.9	36.2
	Total	107,666	....	....	....	791.5	— 1.7	789.8	215.3
17-18	7 a. m. to 1 p. m	26,986	.585	8.689	8.104	218.7	+14.6	233.3	63.6
	1 p. m. to 7 p. m	27,254	.586	8.702	8.116	221.2	+ 4.8	226.0	61.6
	7 p. m. to 1 a. m	27,251	.656	8.471	7.815	213.0	—13.0	200.0	54.5
	1 a. m. to 7 a. m	27,426	.598	5.515	4.917	134.9	— 6.2	128.7	35.1
	Total	108,917	....	....	....	787.8	+ .2	788.0	214.8
18-19	7 a. m. to 1 p. m	27,065	.521	8.649	8.128	220.0	+14.9	234.9	64.1
	1 p. m. to 7 p. m	27,223	.640	9.066	8.426	229.4	+ 3.8	233.2	63.6
	7 p. m. to 1 a. m	27,368	.559	8.860	8.301	227.2	— 7.3	219.9	60.0
	1 a. m. to 7 a. m	27,013	.600	5.639	5.039	136.1	— 9.6	126.5	34.5
	Total	108,669	....	....	....	812.7	+ 1.8	814.5	222.2
	Total for 4 days	434,627	....	....	....	....	....	3,152.7	859.6

TABLE 81.—*Record of water in ventilating air current—Metabolism experiment No. 10.*

Date.	Period.	(a) Volume of ventilating air current.	Water per liter— (b) In incoming air.	(c) In outgoing air.	(d) Excess in outgoing air (c—b).	(e) Total excess in outgoing air (d×a).	(f) Condensed in freezers.	(g) Correction for water remaining in chamber.	(h) Total water exhaled (e+f+g).
1898.		*Liters.*	*Mg.*	*Mgs.*	*Mg.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15–16	7 a. m. to 1 p. m......	26, 823	0. 848	1. 446	0. 598	16. 0	216. 0	+ 81. 7	313. 7
	1 p. m. to 7 p. m......	27, 192	. 772	1. 002	. 230	6. 3	217. 2	+ 17. 6	241. 1
	7 p. m. to 1 a. m......	27, 655	. 750	. 999	. 249	6. 9	227. 2	— 8. 7	225. 4
	1 a. m. to 7 a. m......	27, 705	. 718	. 910	. 192	5. 3	221. 9	— 22. 5	204. 7
	Total..........	109, 375	....	....	....	34. 5	882. 3	+ 68. 1	984. 9
16–17	7 a. m. to 1 p. m......	26, 458	. 757	1. 025	. 268	7. 1	198. 3	+ 25. 6	231. 0
	1 p. m. tc 7 p. m......	26, 866	. 778	. 974	. 196	5. 3	210. 7	+ 3. 7	219. 7
	7 p. m. to 1 a. m......	27, 228	. 788	. 996	. 208	5. 7	238. 4	+ 4. 2	248. 3
	1 a. m. to 7 a. m......	27, 114	. 693	. 919	. 226	6. 1	222. 6	— 16. 3	212. 4
	Total..........	107, 666	....	....	....	24. 2	870. 0	+ 17. 2	911. 4
17–18	7 a. m. to 1 p. m......	26, 986	. 656	1. 035	. 379	10. 2	205. 5	+ 10. 6	226. 3
	1 p. m. to 7 p. m......	27, 254	. 701	. 996	. 295	8. 0	212. 5	+ 6. 3	226. 8
	7 p. m. to 1 a. m......	27, 251	. 694	1. 088	. 394	10. 7	218. 9	— 6. 2	223. 4
	1 a. m. to 7 a. m......	27, 426	. 673	. 991	. 318	8. 7	205. 7	— 14. 7	199. 7
	Total..........	108, 917	....	....	....	37. 6	842. 6	— 4. 0	876. 2
18–19	7 a. m. to 1 p. m......	27, 065	. 711	1. 171	. 460	12. 4	202. 7	+ 24. 2	239. 3
	1 p. m. to 7 p. m......	27, 223	. 757	1. 062	. 305	8. 3	231. 5	+ 24. 6	264. 4
	7 p. m. to 1 a. m......	27, 368	. 738	1. 165	. 427	11. 6	252. 9	+ . 3	264. 8
	1 a. m. to 7 a. m......	27, 013	. 748	. 98	. 240	6. 5	217. 5	— 12. 9	211. 1
	Total..........	108, 669	....	....	....	38. 8	904. 6	+ 36. 2	979. 6
	Total for 4 days	434, 627	....	....	....	135. 1	3, 499. 5	+117. 5	3, 752. 1

TABLE 82.—*Summary of calorimetric measurements—Metabolism experiment No. 10.*

Date.	Period.	(a) Heat measured in terms of Ct_1 to Ct_2.	(b) Average range in temperature between incoming and outgoing water, t_1 to t_2.	(c) Mean specific heat of water for range t_1 to t_2.	(d) Heat measured in terms of C_{20} ($a \times c$).	(e) Change of temperature of calorimeter.
1898.		*Calories.*	*Degrees.*		*Calories.*	*Degrees.*
Feb. 15-16	7 a. m. to 1 p. m	478.0	8.65–12.83	1.0026	479.2	+0.15
	1 p. m. to 7 p. m	467.6	7.95–12.68	1.0028	468.9	....
	7 p. m. to 1 a. m	448.4	8.20–13.60	1.0025	449.5	+1.05
	1 a. m. to 7 a. m	273.5	{ 9.39–15.25 11.59–17.01 }	1.0017	274.0	....
	Total	1,667.5	....	....	1,671.6	....
16–17	7 a. m. to 1 p. m	513.6	7.82–12.01	1.0030	515.1	—.05
	1 p. m. to 7 p. m	512.7	7.23–12.49	1.0031	514.3	+.05
	7 p. m. to 1 a. m	463.2	8.07–14.00	1.0025	464.4	—.05
	1 a. m. to 7 a. m	303.5	9.65–15.63	1.0019	304.1	—.10
	Total	1,793.0	....	....	1,797.9	....
17–18	7 a. m. to 1 p. m	490.4	8.19–12.38	1.0028	491.8	+.20
	1 p. m. to 7 p. m	514.5	7.79–12.53	1.0029	516.0	—.10
	7 p. m. to 1 a. m	460.1	7.99–13.80	1.0025	461.1	+.05
	1 a. m. to 7 a. m	295.2	10.57–16.59	1.0015	295.6	.00
	Total	1,760.2	....	....	1,764.5	....
18–19	7 a. m. to 1 p. m	480.7	8.28–13.33	1.0026	482.0	—.05
	1 p. m. to 7 p. m	529.3	8.01–13.93	1.0025	530.6	....
	7 p. m. to 1 a. m	468.9	8.19–13.58	1.0025	470.1	+.05
	1 a. m. to 7 a. m	285.8	10.54–16.53	1.0015	286.2	—.10
	Total	1,764.7	....	....	1,768.9	....
	Total for 4 days	6,985.4	....	....	7,002.9	....

TABLE 82.—*Summary of calorimetric measurements—Metabolism experiment No. 10*—Continued.

Date.	Period.	(*f*) Capacity correction of calorimeter ($e\times60$).	(*g*) Correction due to temperature of food and dishes.	(*h*) Water vaporized, equals total amount exhaled less amount condensed in chamber.	(*i*) Heat used in vaporization of water ($h\times.592$).	(*k*) Total heat determined ($d+f+g+i$).
1898.		*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Feb. 15–16	7 a. m. to 1 p. m	+ 9.0	+ 3.7	233.7	138.4	630.3
	1 p. m. to 7 p. m	....	— 8.8	226.1	133.8	593.9
	7 p. m. to 1 a. m	+ 3.0	....	238.4	141.1	593.6
	1 a. m. to 7 a. m	....	....	217.7	128.9	402.9
	Total	+12.0	— 5.1	915.9	542.2	2,220.7
16–17	7 a. m. to 1 p. m	— 3.0	+ 6.4	208.0	123.1	641.6
	1 p. m. to 7 p. m	+ 3.0	—12.5	217.7	128.9	633.7
	7 p. m. to 1 a. m	— 3.0	....	251.3	148.8	610.2
	1 a. m. to 7 a. m	— 6.0	....	216.4	128.1	426.2
	Total	— 9.0	— 6.1	893.4	528.9	2,311.7
17–18	7 a. m. to 1 p. m	+12.0	+ 0.9	217.3	128.6	633.3
	1 p. m. to 7 p. m	— 6.0	— 8.9	223.8	132.5	633.6
	7 p. m. to 1 a. m	+ 3.0	....	229.4	135.8	599.9
	1 a. m. to 7 a. m	0	....	208.7	123.5	419.1
	Total	+ 9.0	— 8.0	879.2	520.4	2,285.9
18–19	7 a. m. to 1 p. m	— 3.0	+ 2.8	221.3	131.0	612.8
	1 p. m. to 7 p. m	....	—12.8	242.4	143.5	661.3
	7 p. m. to 1 a. m	+ 3.0	....	267.8	158.6	631.7
	1 a. m. to 7 a. m	— 6.0	....	215.1	127.3	407.5
	Total	— 6.0	—10.0	946.6	560.4	2,313.3
	Total for 4 days	+ 6.0	—29.2	....	2,151.9	9,131.6

The total amount of alcohol excreted as such in the urine, freezer water, and in the air current is shown in Table 83. The total amount per day as thus estimated was 1.1 grams, of which 0.1 gram was excreted in the urine, 1 gram was given off by the lungs and skin and found in the air current and freezer water. The total excretion of 1.1 grams is 1.5 per cent of the total amount ingested. As stated on page 27, we believe that this is in excess of the actual amounts of alcohol given off from the body unconsumed, as there was evidence that part of the material here reckoned as alcohol given off from the body included other organic compounds.

TABLE 83.—*Alcohol excreted by the kidneys and by the lungs—Metabolism experiment No. 10.*

Date.	Period.	Alcohol.					
		Found in urine.	Found in respiratory products. In freezers.	Found in respiratory products. In air currents.	Total excreted.	Total income.	Used in body.
1898.		*Gram.*	*Gram.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15–16	7 a. m. to 7 a. m	0.05	0.26	0.71	1.02	72.49	71.47
16–17	.....do	.08	.06	.88	1.02	72.49	71.47
17–18	.....do	.22	.05	1.05	1.32	72.49	71.17
18–19	.....do	.11	.04	.86	1.01	72.49	71.48
	Total	.46	.41	3.50	4.37	289.96	285.59

Tables 84–87 show the nitrogen, carbon, hydrogen, protein, fat, water, and energy of income and outgo in metabolism experiment No. 10.

TABLE 84.—*Income and outgo of nitrogen and carbon—Metabolism experiment No. 10.*

Date.	Period.	Nitrogen.				Carbon.					
		(*a*) In food.	(*b*) In feces.	(*c*) In urine.	(*d*) Gain (+) or loss (—) *a*—(*b*+*c*).	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) In alcohol eliminated.	(*k*) Gain (+) or loss (—)*e*—(*f*+*g*+*h*+*i*).
1898.		*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Grams.*
Feb. 15–16	7 a. m. to 7 a. m.	19.7	1.4	19.7	—1.4	253.3	11.8	13.7	207.3	0.5	+20.0
16–17	.....do	19.8	1.4	20.6	—2.2	253.3	11.8	14.3	215.3	.5	+11.4
17–18	.....do	19.7	1.4	19.4	—1.1	253.4	11.8	13.4	214.8	.7	+12.7
18–19	.....do	19.8	1.4	18.1	+ .3	253.3	11.8	12.6	222.2	.5	+ 6.2
	Total, 4 days	79.0	5.6	77.8	—4.4	1,013.3	47.2	54.0	859.6	2.2	+50.3
	Average, 1 day	19.8	1.4	19.5	—1.1	253.3	11.8	13.5	214.9	.6	+12.6

The amounts of water in the mixture of alcohol and coffee infusion and the amount of drinking water consumed each day during this experiment are shown in the following table. The alcohol mixture was made by adding to 815 grams of coffee infusion 45 grams of sugar and

80 grams of 90.67 per cent alcohol, making a total of 940 grams containing 822.5 grams water:

Record of drinking water and coffee—Metabolism experiment No. 10.

Date.	Coffee infusion.	Drinking water.	Total drink.
1898.	*Grams.*	*Grams.*	*Grams.*
Feb. 15	822.5	200.0	1,022.5
16	822.5	200.0	1,022.5
17	822.5	200.0	1,022.5
18	822.5	200.0	1,022.5
Total	3,290.0	800.0	4,090.0

TABLE 85.—*Income and outgo of water and hydrogen—Metabolism experiment No. 10.*

Date.	Period.	Water. (a) In food.	(b) In drink.	(c) In feces.	(d) In urine.	(e) In respiratory products.	(f) Apparent loss, $a+b-(c+d+e)$.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15-16	7 a.m. to 7 a.m	922.1	1,022.5	62.3	1,049.8	984.9	− 152.4
16-17	....do	922.1	1,022.5	62.3	1,264.2	911.4	− 293.3
17-18	....do	922.1	1,022.5	62.3	1,637.6	876.2	− 631.5
18-19	....do	922.1	1,022.5	62.3	1,133.1	985.6	− 236.4
	Total, 4 days	3,688.4	4,090.0	249.2	5,084.7	3,758.1	−1,313.6
	Average, 1 day	922.1	1,022.5	62.3	1,271.2	939.5	− 328.4

Date.	Period.	Hydrogen. (g) In food.	(h) In feces.	(i) In urine.	(k) In alcohol eliminated.	(l) Apparent gain, $g-(h+i+k)$.	(m) Loss from water $(f\div 9)$.	(n) Total gain (+) or loss (−) $(l+m)$.
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15-16	7 a.m. to 7 a.m	41.3	1.6	3.2	0.1	+ 36.4	− 16.9	+19.5
16-17	....do	41.4	1.6	3.4	.1	+ 36.3	− 32.6	+ 3.7
17-18	....do	41.3	1.6	3.2	.2	36.3	− 70.2	−33.9
18-19	....do	41.4	1.6	3.0	.1	+ 36.7	− 26.3	+10.4
	Total, 4 days	165.4	6.4	12.8	.5	145.7	−146.0	− .3
	Average, 1 day	41.4	1.6	3.2	.1	+ 36.4	− 36.5	− .1

TABLE 86.—*Gain or loss of protein* ($N \times 6.25$), *fat, and water—Metabolism experiment No. 10.*

Date.	Period.	(a) Nitrogen gained (+) or lost (—).	(b) Protein gained (+) or lost (—) ($a \times 6.25$).	(c) Total carbon gained (+) or lost (—).	(d) Carbon in protein gained (+) or lost (—) ($b \times .53$).	(e) Carbon fat, etc., gained (+) or lost (—) ($c—d$).	(f) Fat gained (+) or lost (—) ($e \div .765$).
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15–16	7 a. m. to 7 a. m	—1.4	— 8.8	+20.0	— 4.7	+24.7	+32.2
16–17	.....do	—2.2	—13.7	+11.4	— 7.3	+18.7	+24.5
17–18	.....do	—1.1	— 6.9	+12.7	— 3.6	+16.3	21.3
18–19	.....do	+ .3	+ 1.9	+ 6.2	1.0	+ 5.2	+ 6.8
	Total, 4 days	—4.4	—27.5	+50.3	—14.6	+64.9	+84.8
	Average, 1 day	—1.1	— 6.9	+12.6	— 3.6	+16.2	+21.2

Date.	Period.	(g) Total hydrogen gained (+) or lost (—).	(h) Hydrogen in protein gained (+) or lost (—) ($b \times .07$).	(i) Hydrogen in fat gained (+) or lost (—) ($f \times .12$).	(k) Hydrogen in water, etc., gained (+) or lost (—) $g—(h+i)$.	(l) Water gained (+) or lost (—) ($k \times 9$).
1898.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feb. 15–16	7 a. m. to 7 a. m	+19.5	— .6	+ 3.9	+16.2	+145 8
16–17	.....do	+ 3.7	— .9	+ 2.9	+ 1.7	+ 15.3
17–18	.....do	—33.9	— .5	+ 2.6	—36.0	—324.0
18–19	.....do	+19.4	+ .1	+ .8	+ 9.5	85.5
	Total, 4 days	— .3	—1.9	+10.2	— 8.6	— 77.4
	Average, 1 day	— .1	— .5	+ 2.6	— 2.2	— 19.4

TABLE 87.—*Income and outgo of energy—Metabolism experiment No. 10.*

Date.	(a) Heat of combustion of food eaten.	(b) Heat of combustion of feces.	(c) Heat of combustion of urine.	(m) Heat of combustion of alcohol climinated.	(d) Estimated heat of combustion of protein gained (+) or lost (—).	(e) Estimated heat of combustion of fat gained (+) or lost (—).	(f) Estimated energy of material oxidized in the body $a-(b+c+m+d+e)$.	(g) Heat determined.	(h) Heat determined greater (+) or less (—) than estimated $(f-g)$.	(i) Heat determined greater (+) or less (—) than estimated $(h \div f)$.
1898.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
Feb. 15–16, 7 a. m. to 7 a. m....	2,709	127	140	7	— 51	+303	2,183	2,221	+38	+1.7
16–17, 7 a. m. to 7 a. m....	2,709	127	162	7	— 78	+230	2,261	2,312	+51	+2.3
17–18, 7 a. m. to 7 a. m....	2,709	127	148	9	— 40	+200	2,265	2,286	+21	+ .9
18–19, 7 a. m. to 7 a. m....	2,709	127	139	7	+ 11	+ 64	2,361	2,313	—48	—2.0
Total for 4 days..	10,836	508	589	30	—158	+797	9,070	9,132	+62	+ .7
Average 1 day	2,709	127	147	8	— 40	+199	2,268	2,283	+16	+ .7

The average daily income of energy in this experiment—i. e., the estimated heat of combustion of material actually oxidized in the body—averaged 2,268 calories per day; and the outgo—i. e., the heat given off from the body and measured—amounted to 2,283 calories. The measured outgo was thus 1.8 per cent larger than the theoretical income. It will be noticed that the energy of income and of outgo were practically identical with those in the preceding experiment (No. 9). Here, as in experiment No. 7, the alcohol was almost completely oxidized. The kinetic energy resulting from that oxidation agrees very closely with the potential energy of the same amount of alcohol as measured by its heat of combustion as determined by the bomb calorimeter, and the alcohol served to protect body protein and fat from oxidation.

As the results of other experiments of this series are now being prepared for publication, the discussion of those here described is reserved until the data of a larger number can be included.

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Experiments on the metabolism